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SUBJECT:

Electrical Notes of a Trans-Atlantic Trip.

By THOMAS D. LOCKWOOD.

SPECIAL MEETING, OCTOBER 29TH, 1889.

SUBJECT:

Some Methods of Regulating Accumulators in Electric Lighting.

By GEORGE B. PRESCOTT, JR.

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3824 ?
A paper read before the 35th meeting of the American Institute of Electrical Engineers, New York, October 15th, 1890, and discussion thereon. Past-President Franklin L. Pope in the chair.

ELECTRICAL NOTES OF A TRANSATLANTIC TRIP.

BY THOMAS D. LOCKWOOD.

Although the English *Electrical Review* has heretofore been so good as to intimate in speaking of some of my pen productions, that they are characterized by such a mixture of practical information and humor as only a true born American could produce, yet it is a fact, as some among you have long been aware, that I am of English parentage and birth, and lived in England for the first sixteen years of my life.

It thus came about that I was more easily enabled to assimilate in habit and thought with the English electricians whom I had the good fortune to meet, than is usual, and my visit, so far as the British Isles were concerned,—though the first one in twenty-four years—was much like the return of a wanderer to his home.

The most difficult part of this paper was the choice of a suitable designation therefor. I cogitated over many; among others, I thought for a moment of denominating it "A Visit to Europe and the Bull;" the Bull, of course, being playfully indicative of the domain of John of that ilk.

Calm contemplation, however, showed me that "Europa and the Bull" were out of question, and that such a title would have appeared in the highest degree anomalous to those who consider the United Kingdom as constituting a part of Europe. Moreover, it might be thought by others that as I spent so little time on the Continent of Europe and saw so little of it, I was not authorized to speak so grandiloquently of my humble few days in France and Belgium; and inasmuch as many of my observations,—for example those on outdoor electrical construction—are equally applicable to continental and insular Europe, there might be some doubt in the minds of my auditors whether there was any clean

cut line of differentiation between the two elements of such a combination title.

Indeed, while myself considering this composite caption, I was forcibly reminded of a remarkable passage in the life of the late Alfred Smee (he who was principally known as the inventor of the Smee battery, in which polarization was prevented or materially retarded, by making the negative plate of silver, coated with finely divided platinum), but who was really one of the most able of the early electricians and electro-metallurgists, and a general philosopher of high merit.

Mr. Smee, during the years 1845 to 1847, took a great interest in the potato disease, and his view that the disease was produced by the ravages of a variety of aphides excited considerable rancorous animosity and ridicule.

In a pantomime exhibited at Drury Lane, appeared the following:

Scene—A village with shows, etc.—little boy looking at a peep show.

Showman loquiter—"This is the aphid vastator as you may see, very much magnified by Mr. Smee." Boy—"Please, sir, which is the aphid and which is the tater?" Showman—"Which-ever you like, my young investigator"

And in the same manner had I chosen the enterprising title already referred to, my hearers might have felt disposed to enquire: "Which is Europa and which is the Bull?"

My excursion, from the time I left home until the day of my return, extended over a period of twelve weeks, minus two days. I sailed from Montreal in the steamship "Vancouver" of the Dominion Line, and had a short passage and over 48 hours of river and gulf sailing.

Passengers taking this route have a very short sea space and a correspondingly long and delightful smooth water and land-locked experience; they have a greater chance of seeing icebergs, whales and porpoises, with a certainty of cooler weather and a reasonable possibility of rougher seas. I returned in the "City of Rome," the only Anchor Line steamer plying between Liverpool and New York.

I staid on my arrival in England a few days in Liverpool, passed on to the Derbyshire peak district, then to Birmingham. From thence I went to London, making my headquarters not in the city, but in a most beautiful town, Tunbridge Wells, which

is an inland watering place some thirty miles distant, in Kent. Later I passed over by way of Dieppe to Paris, and after a few days there, returned to England through Brussels and Antwerp.

After staying a few days more in London, I went to Scotland, calling at the Cathedral cities of Lincoln and York, and at the manufacturing city of Newcastle-on-Tyne. I halted at Edinburgh, passing on later to Inverness, via Perth; and then down the Caledonian canal to Glasgow, and back to London, stopping en route once more at Edinburgh. Then I took a side trip from London to Salisbury, Bath, Gloucester and Worcester, and again returned to London via Oxford. Finally I started from London to Chester, a most charmingly antiquated walled city, visited some of the North Wales watering places, inspected the mediæval castles of Conway and Carnarvon, climbed Snowdon, sailed from Holyhead to Dublin, took railway to Cork, passing the celebrated Blarney castle and stone, spent a day at Killarney, and took ship at Queenstown.

My visit was not a business trip, and I made no attempt to combine pleasure and business, but it is hardly necessary to say that I did not travel with my eyes shut; and that when anything electrical came before me, I had no hesitation in making observations on it. However, my observations were somewhat desultory, and my account of them will necessarily also partake of that character.

TELEGRAPHY.

I saw little of interest in telegraphy until my arrival in London, where I lost no time in looking up William H. Preece, the well-known electrician of the British telegraphs, whose urbanity and good nature were as usual far above par. By his favor I was able to inspect the central telegraph station, which is located in an immense building in St. Martins Le Grand, just opposite the general post-office building proper.

I was placed in the care of Mr. Cooper, a genial gentleman, charged to a high potential with useful information, and in his company paid my respects to H. C. Fischer, the controller of the central station.

Mr. Fischer, with whom I had had some previous acquaintance during his visit to America in 1877, made strenuous efforts to recollect me, and I think succeeded, although I am not sure. But if his recollection was not perfect, it was at least a good imitation, and did not in the least interfere with the cordial reception which I received at his hands.

The London operating room, or rooms, is an immense affair. Heretofore I had a most exalted opinion of the size of the Western Union room in New York, but the London room was a decided revelation. I noticed a very peculiar effect there. When first introduced, a good sized room filled with operators, or more properly telegraphists, and apparatus dawned upon my vision, and together with Mr. Cooper and the superintendent in charge, I wandered through it; but near the end we suddenly turn a corner, and another vista as wide and long as the first, appears, which again we traverse only to find once more as we approach its farthest limit, that a third vast expanse lies before us, and so on apparently for half a dozen successive times. Then I was led upstairs where a similar succession of rooms was exhibited to my bewildered gaze.

Morse instruments, both sounder and ink writer, were there to be found. The single needle also appeared to hold its own, and I saw something new to me, viz., telegraphists reading by sound from the click of the single needle as it vibrated from one side to the other, striking its limiting stop.

With respect to the Morse, I do not think the average transmission is as fast as is the American average, nor do I think it possible to achieve extremely rapid sending with the heavy keys generally in use.

I was greatly interested with the way in which the Delany multiplex has been taken up by the British telegraphic authorities. It may have been in some degree improved and modified, and I understood that the number of circuits simultaneously worked successfully, were not as great as had been hoped for, but still it was in use; its use was increasing, it was doing good work on lines of considerable length, and the operators liked it.

Upon making inquiries about the Wheatstone automatic, it was to be noted that while authorities united in enthusiastic praise of its qualifications as a fast telegraph in all cases where the matter transmitted was to be received in duplicate or in multiple, such as news, the praise was by no means so emphatic with respect to its ordinary use as a means of transmission for business messages, as so much time was required to be taken up in the preliminary measure of punching.

The Pneumatic Dispatch branch of the London station is on an equal scale of immensity, and in fact is one of the great features of London telegraphy. Throughout the length and breadth

of the land I found civility and prompt attention in the matter of receiving and delivering telegrams. Early and late I tested the telegraphic service, and found it up to the mark.

It is, I believe, a regulation that all telegrams are to be prepaid by stamp; the said stamps in all cases to be affixed by the sender. The former of these provisions is no doubt invariably carried out, but as the latter is not always, I cannot speak positively as to either.

As a matter of fact I was rarely required to affix my own stamps in telegraph offices in large cities, whereas the letter of the law was fully carried out in small places, the principle being, I suppose, at these places, to make up in formality for what was lacking in amount of business.

The facilities for telegraphy in the United Kingdom are wonderfully complete, and I found no place too small for a telegraph office; moreover in my opinion, telegraphy is there cheap, in spite of the fact that the address and signature has to be counted in and paid for.

The dynamo does not appear to be employed as a source of telegraphic currents, and here, I think the British telegraph system is a little behind the times. Yet, as far back as 1873, I understand that Mr. Preece experimented with the Gramme machine for this purpose, but found it too unsteady for the Wheatstone automatic instruments.

There are 2,300 cells of battery in use at the central station in London, and 220 circuits are supplied by accumulators.

Do I approve of the telegraphs being owned by the government? In a monarchy, whether limited or absolute, yes. Because the government is permanent and usually stable. It answers well in England; it is cheap and good. But does it pay? Well, if you consider that the agencies of a government should be administered for the people's benefit, I think it does. But for a republic, at least one like ours, in which radical and sweeping changes of administration occur at frequent intervals, I am clearly of the impression that a government ownership would be an unqualified evil. No doubt a government control leads to a superabundance of red tape; to the ridiculously excessive formalities of the "Circumlocution Office;" and to extreme conservatism. It also acts as a damp sheet upon invention. Yet in spite of these tendencies, the telegraphs of the British Isles are, I think, on the whole, better managed and better manned, than

they would be by one or more corporations; and the question of remunerativeness seems to me quite of a secondary character, since even though the telegraph department be not profitable, it seems at least evident that the people are enjoying a lower rate than they would under other circumstances be entitled to or receive.

The rigid use of discipline was, however, well illustrated in an attempt which I made to see the telegraph office at Birmingham, but where I was told that they would have to write to London for permission to allow my visit. I could not wait the exchange of correspondence and thus have not as yet seen the telegraph office there. It seems the telegraph department does not use its wires at all on office business, but employs the mail altogether, the wires being reserved exclusively for paid business.

ELECTRIC LIGHTING.

From my point of sight as an electrical engineer I was disappointed to find that electric street lighting was, comparatively speaking, still a thing of the future nearly all over the Kingdom. Not that electric lighting is not being done, but that so little of what can be done is seen. Instead of having electric illumination all around you as we have it, we have, so to speak, to hunt up installations.

There are a number of central station plants in London, but London is an immensity and might contain many more, and yet electric lighting would be conspicuous by its paucity. You may, for example, walk through Holborn and Oxford streets and see lines of glorious shops lighted electrically; you may go to Grosvenor gallery and watch the historical illumination there; and you may at various factories see that the electric light is for this class of work being extensively employed.

The Great Western Railway station at Paddington is lighted up by 100 arc lamps and an infinity of incandescent hairpins; and many seaside resorts know of the electric light; while at Glasgow and Liverpool are central lighting stations of high capacity, but in spite of all this, you cannot help forming and bringing home the impression that there has been but little done in comparison with the immense amount which remains undone in this branch of electrical application. The truth is that the British public seems to have had a surfeit of electric lighting companies at an early date, with all that an electric lighting

company implied in the years 1878 to 1882, and has of late years had no wish to take a second dose.

As a telephone electrician, I felt disposed to congratulate the telephone and telegraph people that they had escaped the horrors of burned out central stations and disturbed circuits.

Such lighting companies as may hereafter undertake to occupy this field are also to be congratulated that they will have the several years' experience of others, and all of the many improvements which have been produced in apparatus and insulation to profit by. I think that municipalities in England will themselves shortly take up this matter. In no case, I am sure, will "undertakers' wire" or the reckless class of construction which we have too often seen in this land of liberty be tolerated.

Isolated house lighting, is however, well advanced. Inquiries which I made proved that this branch of incandescent electric lighting which has overflowed upon the steamships and boats is very popular. In the several examples of it which came under my personal notice, the electricity is drawn from secondary batteries, which are during the day charged by a dynamo.

I had the happiness of dining with W. H. Preece, at his house at Wimbledon, and of examining his lighting plant. He uses the secondary cells of the Electrical Power Storage Company. The plates are formed of a leaden grid, the perforations of the positive plate being filled originally with minium, while those of the negative plate are filled with litharge. The charging dynamo was run by a gas engine, and Mr. Preece informed me that it cost him exactly as much for gas as it did when he used gas for illuminating purposes, while he had a much greater amount of light. I am bound to state, that in my opinion, the light was superb, being apparently softer and more equable than when obtained directly from the dynamo.

While upon this subject I may state that I also had the pleasure of inspecting the beautiful laboratory and workshop of Sir David Salomons, at Broomhill, Tunbridge Wells. Sir David is a wealthy amateur who has made the realm of secondary batteries peculiarly his own, and who has written a textbook on their construction and care, which, if not absolutely faultless, is certainly the most useful and practical work on the subject in existence. He has a pair of fine compound steam engines and several dynamos, these being connected with the prime motors by leather link belts of American manufacture.

A great number of storage cells, several hundred I should judge, and in prime condition, are located in a side room, floored with glazed tile, the entire floor sloping to one side for purposes of drainage. In the machine shop I saw some of the finest machine tools that my eyes have ever fallen upon, lathes, drills, planers, shapers and so forth, and it was particularly noticeable that each machine was provided with its own electromotor. All of the motors were of the Elwell-Parker make. Upon a shelf in the laboratory office were a few well-chosen books, among which I noticed the last bound volume of the proceedings of this Institute.

Sir David uses these motors for every conceivable purpose, furnishing electric light and power for his entire establishment, and while I was there, electricity was employed in making butter. If an electrician, whose heart is in his work, is ever justified in cherishing envy in his bosom, it is when visiting such a place as that of Sir David Salomons, and he has my heartiest acknowledgments for the kind way in which he allowed me to inspect the same, though himself absent.

I saw throughout my travels little in the motor line, except those to which I have referred, but I am informed that the use of electromotors in Britain is already great, and is rapidly increasing.

TELEPHONY.

The chief centers of good work in telephony are Dundee, Glasgow, Liverpool, London, Edinburgh, Manchester and Birmingham. The fact that I mention Birmingham last, shows that no attempt at classification has been made. I could not inspect the Liverpool central station as I happened to be there only during holidays, when the authorities were all absent, and for lack of time I was unable to visit Manchester at all, but I saw a good deal of the Liverpool outside construction, and I heard enough about Manchester, to assure myself that the installation was par excellence.

Many of you will be aware that three of the principal telephone companies in England, viz., the United, the National and the Lancashire and Cheshire, have recently joined their forces under the name of the National Telephone Company, Limited.

This company has now taken charge of the London Exchange, where I was rather surprised to find that there were already more than 7,000 subscribers.

There, nearly all lines were built over the housetops, with tubular iron fixtures of a construction, beautiful and light and yet strong. A very peculiar feature of this London construction was that the wires of a route were, as a rule, all strung in a vertical plane, there being very few cross-arms. This made a very symmetrical appearance, but it struck me that it was hardly a sufficient utilization of a route, or, as the Britons say, of the "way leave." This, however, was the work of the United Company, and I think was not in accordance with the judgment of the engineer of that company, who remains in the same capacity with its successor.

The post office department charges the telephone companies a regular royalty, it having been legally decided that the telephone is a "telegraph" within the meaning of the statute. The postmaster-general apparently does not like the action of the companies in uniting, although none of them were competitive, but all working in distinct territories. There is no doubt, however, that he fears that the capitalization will unnecessarily enlarge and will be a big bite for the government mouth whenever, and if ever, purchase may be decided upon.

It does not seem to be likely that the postmaster-general will take any steps to harass the companies, nor do I believe that the post office telegraph department will care for a long time to come to trouble itself with telephony, and it is my opinion that the remaining telephone companies will soon in turn be absorbed or otherwise united with the National Company.

Long line telephone work in Great Britain is, of course, limited by the size of the island and by the peculiar relative position of the large towns. I found very good talking between Birmingham and the several towns of Sheffield, Derby and Nottingham; between Glasgow and Edinburgh and Dundee; and especially fine from Sunderland to points upward of a hundred miles distant. For these latter distances circuits had to be artificially made up. In London there are necessarily many central telephone stations. No one who has not seen and studied London can form an idea of its vastness, and by reason of this vastness there will always be (notwithstanding the manifest excellencies of centralization) a plurality of central stations connected by trunk lines, mainly converging to a principal trunk station, but supplemented by a sufficient number of trunks between such central stations as are adjacent to each other. Yet I should say that there are at present

too many central stations and that they are too close together, and I am under the impression that the present management thinks so, too, and will condense closely grouped central offices considerably.

In Scotland I found a regular multiple switch-board in the Glasgow central station, which was the most American looking central station which I have seen anywhere. In Glasgow, also, a "nickel in the slot" toll-box has been devised, and is largely used at public stations, a penny or a certain number of pennies being the local charge, and a sixpence, or more, the trunk line or out of town charge. The operator can tell by peculiar sound signals automatically given by the passage of a coin or coins whether the proper amount is dropped in, and if not, the machine simply absorbs what has been put in and does not grant the desired accommodation. Regular subscribers have a check key which operates the apparatus without requiring the electro-deposition of a coin. This machine is well spoken of, and is said to give satisfaction. In some other parts of England these boxes are also used, and non-subscribers to the exchange may purchase a local check key for the purpose of using at any time the public station without having to pay every time. It may be of interest to state that at every railway station in England the "nickel in the slot," or rather the "copper in the slot" machine, applied to a variety of uses, is to be found. The weighing machine is the most popular, but the electrical shocking machine is a close second.

The best working long lines which I found were without doubt those belonging to the Northern District Telephone Company. This company is in charge of C. B. Clay, of Sunderland: the lines are new and are built of the latest model.

In Newcastle, all lines, both telegraph and telephone, which are owned by the government, are underground. They work very well, and the government telephone system there is ably managed by A. W. Heaviside, who based his telephone exchange upon a pro-telephone exchange, actually existing in Newcastle, and operating dial telegraphs long before the telephone exchange was thought of, or the telephone itself invented.

The National Telephone Company is fortunate in having such men as Messrs. Bennett, Coleman, Jackson, Phillips, Sinclair, and as far as possible employs men trained by previous education and experience to be equally efficient in a business and technical capacity.

As to electrical construction outside, I may say without hesitation, that the average is far above ours, whether telegraphic, telephonic or otherwise. The poles are no longer than are necessary, are uniformly well trimmed and painted, and above all are well stayed. Mile after mile I have ridden on a railway both in England and on the Continent and found every pole "stayed," or as we would say "guyed." The cross-arms are usually short, and project alternately a greater distance to one side or the other—that is, the upper cross arm may carry two insulators on the right side of the pole and but one on the left, while the next will reverse that, two being on the left and one on the right, and so on. The telephone companies had much housetop construction, but the same system of staying prevailed, so that the construction was superb, even though the roofs were all of the pitched variety. In Sunderland only, and the other towns where the Northern District Telephone Company holds sway, are to be found long cross-arms à la American, the idea having being imported by Mr. Clay, who visited the United States a year or two ago, and who is a manager of the most progressive type.

In Edinburgh, though nearly all wires were overhead, they were so symmetrically arranged as to be hardly noticed. A. R. Bennett, who is general manager of the Edinburgh district, looks also after Dundee, Galashiels, Dumfries and many other towns. The above remarks apply alike to the government construction in Great Britain, France and Belgium, and to the construction of telephone companies.

The only underground telephone line work which I found was the well known Paris sewer work and the government telephone exchange wires at Newcastle-upon-Tyne; but the National Telephone Company is beginning to lay some underground wires in Birmingham.

At Birmingham I also noticed some little pole work, and it was both amusing and instructive to see that, wherever possible, the poles were modestly planted close to the gable end of a block of buildings, or inside of a high fence, or in the corner of a vacant lot, so as to attract as little notice as possible.

I found that silicon bronze wire was well thought of throughout the several territories which I visited, and in general use. It can be made of a conductivity nearly as high as copper, while it is tougher; and it is much better for telephone work than iron, because not only is the conductivity higher but it possesses a much lower co-efficient of self-induction.

One telephone span I saw in the south of England crossing the opening of the Dartmouth harbor, which was certainly not much less than half a mile in length. I venture the prophecy that in the near future we shall use silicon bronze here in the United States much more than heretofore we have done.

In France I visited of course the Exposition, and met Messrs. Abdank-Abakanowicz and Berthon, both old friends. The finest electrical affair about the Exposition, to my mind, was the way in which the great fountain was illuminated in kaleidoscopic colors every night. This has, of course, often been done before, but never, I think, so perfectly or on such a scale. The success of the installation is due to Mr. Aylmer, who has had it in charge.

I stood in the tower and admired, and then I went down through the tunnels and stood beneath the fountain, where the arc lights were reflected through colored screens and through the plate glass floor, and marveled and admired still more, especially when I saw how the levers arranged in the tower like those of the Pennsylvania railway signal tower, worked pneumatically the screen mechanism below, and kept an ever-changing succession of beautiful colors upon the different fountain jets; and all this apparently, so far as the crowd could see, working itself; for there was no manifest link between the operating tower and the fountain.

The Exposition telephone station, as arranged by L. Berthon, was a sight in itself, with its multiple switch-board, its closets for private communication, its samples of fine electrical apparatus made by the Societe Generale des Telephones, and its apparatus and circuit arrangements for receiving operative performances and re-issuing them for the delectation of numerous auditors.

Long telephone lines stretch from Paris to Havre, Lille, Bruxelles, Lyons and Marseilles, and work admirably. These are chiefly of copper and are arranged in metallic circuits.

Mr. Berthon, the managing engineer of the Societe Generale des Telephones, told me that his company while sparing no effort to keep up its efficiency, had for some little time been resting on its oars in view of the possible purchase of its telephone property by the government. And, as you are aware the government has since decided to acquire this property, and has in fact taken possession of it, which action, I believe, to be an unfortunate one, alike for the government, the society and the people.

Of course the great Edison exhibit with its 9,000 feet of floor space was a tremendous affair; and, although it would naturally impress the observer without any extraneous aid, it is fair to say that its merits were literally hammered into the visitor's mind by the able enthusiast who had it in charge.

This, together with the surprisingly fine exhibit made by the Thomson-Houston company in association with the Thomson Electric Welding company, and also the unique historical exhibit made by the American Bell Telephone company, fully redeemed the electrical section from any participancy in the otherwise too true charge that the share of America in the great exposition was comparatively insignificant.

The compound engines, built by Messrs. Davey, Paxman & Co., of Colchester, England, to run the dynamo for lighting the fountain tower, and exhibition, were an interesting sight to me. I was delighted to watch their fine and speedy regulation as the requirements varied. The young man who was running them, was a rising electrician, H. D. Wilkinson, the same who succeeded Mr. Kennelly in the authorship of the series of electrical measurement articles lately published by the London *Electrician*.

Mr. Wilkinson, believing it right to give himself a practical intimacy with all branches of electrical engineering, was taking this method of doing so, and illustrating the English tendency to carry out to the fullest extent the scriptural maxim "Whatsoever thy hand findeth to do, do it with thy might."

I was favored by Messrs. Siemens Bros. & Co., by permission to visit their works at Charlton, Woolwich. There I found active work going on in all branches of electrical manufacture, but the most new and interesting feature to me was the submarine cable work which I witnessed in various stages. This I could not avoid reflecting, is the one branch of electrical work in which Britain is practically without competition. Here I met Frank Jacob, the electrician of the Siemens company; a remarkably able and intelligent man, and the inventor of one of the earliest systems of multiple telephony and combined telephony and telegraphy. A most interesting feature of the Siemens works is the testing room, where every foot of cable is tested during the process of manufacture. Immediately across the river and thus an opposition physically as well as commercially, is the rival cable establishment of Silvertown.

Speaking of manufactories, brings to mind that the tendency

of the British business public to consolidations (or amalgamation as it is mercurially termed), after having swept over all the breweries, distilleries and gas companies within reach, and after having touched the telephone companies, is now exerting itself upon the electrical manufacturing interests, as evidenced by the fact that all of the storage battery companies and electric railway companies have amalgamated to form "The Electric Construction Corporation, Limited," and that the various Woodhouse and Rawson manufacturing companies have also consolidated into a large joint stock corporation.

While in Birmingham, and engaged in visiting the local lions, I went to see Aston Hall, the free museum of the town. In one of the many interesting rooms there, I observed on exhibition, an old fashioned large magnetic machine designed, as an inscription thereon informed me, for use in electroplating. Upon close inspection, I found it to be the first magneto machine ever designed for that purpose; namely, that made and patented in 1842 by Stephen J. Woolrich. This machine was presented to the museum, by Thomas Prime & Son, electro-metallurgists of Birmingham.

Passing through the cathedrals and abbeys of Great Britain, my bosom, like that of Sir Joseph Porter, K. C. B., swelled with pride, to note how these buildings and their precincts were made into a species of mundane Valhalla, where the worthies of the nation, distinguished in war, science or literature were immortalized, and their memories treasured, for the example and encouragement of their countrymen, and as a mark of appreciative acknowledgment of their services rendered to their country.

In Westminster Abbey I remarked the tombstone of William Spottiswoode, electrician and philosopher; while in the abbey and churchyard of Melrose, I noticed respectively the graves of Michael Scott, and Sir David Brewster, one, the friend of True Thomas the Rhymer, of Ercildoun, and the scientist par excellence of the fourteenth century; the other, one of the most fortunate wizards of the nineteenth century; Michael in his day was called a "wizard," but would probably now be called an electrician.

In conclusion, I desire to say that the cordial and fraternal manner in which everywhere I was received by electricians, and by those interested in electrical development, and the hearty hospitality which I received, merit and receive on my part the

profoundest appreciation and the warmest reciprocal feelings of kindness. Never from the moment that I set my feet on European shores, until the moment of my departure, had I any need to feel that I was a stranger in a strange land.

DISCUSSION.

THE CHAIRMAN (Mr. Franklin L. Pope): We have listened with much pleasure, not unmixed I hope with profit, to Mr. Lockwood's interesting paper. In no way is there more to be learned than by comparing with our own work, that which has been done in other countries, by men who are working out these problems on their own lines and under different conditions. By what Mr. Lockwood has said about the English telegraph service, I am reminded of one or two features of it which struck me as being exceedingly convenient. One of them is the method of prepaying the telegrams by stamps. The rate is sixpence for twelve words, counting the address and signature. Each additional word is a halfpenny and the ordinary postage stamps are used indiscriminately for letters and telegrams. The convenience of this appears, as it did to me two or three times, when traveling a long distance on an express train which sometimes does not stop for two or three hours. Having occasion to send a telegram for some one to meet me at a point ahead I have written my message while on the train, put stamps on it, wrapped up three or four coppers with it for "backsheesh," and thrown it off at a way station; and I have always found that it was dispatched and received in due time at the point of destination. That is a very great convenience. There is another feature that will strike our people as a little curious, and that is that in English telegraphing there are no dead-heads. If Mr. Preece sends a telegram he has to put stamps on it, and if Queen Victoria sends a message, she also has to put stamps on. Office messages are sent by mail and paid by postage stamps.

Mr. Lockwood has referred to the construction in England, and the careful manner in which the poles are stayed. That is very largely due to the costliness of timber, rendering it necessary to use light sticks of timber where we would use heavy ones, and stiffening them with stays, so that the general appearance of their

lines is a very large proportion of wires and insulators to a very small allowance of pole. It gives them a rather neater appearance than ours in some respects, but I doubt whether it is much more substantial, although there is no question that the fastening of the wires and of the insulators is much more substantial than ours, and that is particularly the case on the continent.

DR. ALLAN V. GARRATT:—Mr. Lockwood has spoken of the excellence of construction in England. We have heard through the English journals from time to time in regard to the rules and requirements enforced there. If Mr. Lockwood would kindly tell us about the system of inspection for inside electric light wires in England, and the conflicts, if any, between the insurance and the electric light people, it would be interesting and instructive.

MR. T. C. MARTIN:—With regard to that very interesting topic suggested by Dr. Garratt, I think we might have some light thrown on the subject by a gentleman here this evening, and known to a great many of us by his extremely able and lucid writings. I refer to Mr. G. L. Addenbrooke, of England. That gentleman is now on his way home from Australia, where he has been engaged in putting in several plants on steamers. He has been associated with Mr. Ferranti in London in a large portion of his work there. I know of no more interesting work at the present time than that which Mr. Ferranti is doing. It transcends in many respects anything we have done or contemplate doing, and the experience derived from it, I think, would be extremely valuable to us. I think Mr. Addenbrooke's experience in operating the station at the Grosvenor Gallery, and also from running the overhead circuits in the streets, might be profited by in this city, and regarding which various statements have recently been made with more or less truth. But before Mr. Addenbrooke favors us in that way I would like to call attention to one extraordinary omission from the paper. It is probably due to the fact that there was no information obtainable. I refer to the fact that there is no mention in the paper of electric railroading. At the present time in this country we have in something over 100 cities, counting roads, branches and extensions, 179 electric railways. By the end of the year they will operate some 1,200 miles of track. Over that track will run something like 1,800 to 2,000 cars. In view of the fact that we have such an extension here, and that it meets with such universal approval; and that Mr.

Lockwood with all his keen observation—and we know him to be a most observing man—should have seen nothing of the kind whatever to arrest his notice or attention in England, is something phenomenal, and it would be interesting to know what causes that. Does the difference lie in conservatism? Does it lie in local conditions altogether apart from national temperament? Does it lie in the obstructiveness of the local authorities? Does it lie in the caution of capital, or what? What is the reason? There must be some reason and even if it be a bad one, there probably is an argument to offer for it.

Another very interesting point in the paper, was the use of stationary motors. Mr. Lockwood said that he understood the use of such motors to be on the increase in England. I have been at some pains to ascertain whether that is a fact, and I cannot find that the use of such motors is very largely increasing, and the reason seems to be there are no stations to supply the current, and naturally there are no motors. But an explanation has recently been offered by Mr. Van Rysselberghe of Belgium. It is proposed at the present time to introduce electric lighting pretty extensively in Brussels, but Mr. Van Rysselberghe seems to think there is no use for a central station. In his opinion everybody who wants the electric light should generate the current himself and supply himself, and for that reason in place of a central station, as we know it in America, he proposes to put in hydraulic motors to drive independent plants, these hydraulic motors to be worked by the high-pressure hydraulic service of the city. Mr. Van Rysselberghe, in explaining his system recently, said that he did not think there was any reason at all for the introduction of the electric motor on the Continent; that the European consumer wanted something simpler than the electric motor. How he would get it, I find it hard to conjecture, but such he said to be the case. I have listened with a great deal of interest to Mr. Lockwood's paper, and would be very glad indeed if he could give us light upon one or two of these points which I have suggested. I would suggest that Mr. Addenbrooke's experience with regard to the work in connection with the Ferranti installation in London is of the most interesting and valuable nature; and now that the Deptford station is going into operation, and is a practical development of the results obtained at the Grosvenor Gallery, I think it would interest us to know what he has done there himself.

Mr. G. L. ADDENBROOKE :—I should be only too glad to say anything that I can, premising my remarks with the statement that I have been away from England very nearly a year, chiefly in Australia, and that I came here to find out what they had been doing in England. I rather came here to hear the latest news than to be able to say anything myself. It is a great pleasure to have heard Mr. Lockwood speak so appreciatively of the overhead work in England. We have felt satisfied ourselves that our overhead work had a good many defects in it, but in England we look a great deal to people in America, and Mr. Lockwood having such thorough experience, and speaking so well of what we have accomplished, it gives us a great deal of gratification, especially as I happen to have been connected with the work in various capacities myself, both telephonic and electric lighting. In referring to overhead electric light work I am speaking rather of the past than of the future, because I think you are aware the commission appointed by the Board of Trade, which has lately gone into the whole matter, has formed a set of regulations under which the whole of the electric lighting in London is to be placed underground as soon as possible. No additional overhead wires are allowed to be placed, except such as may be agreed upon between the inspectors and the various companies, and the central station companies in London are now very hard at work laying down mains. However, there is no doubt a good deal of overhead work will be required for various purposes, and as you have so much overhead work here perhaps it might be worth while to explain our practice. First of all, we have not been allowed to plant posts in the streets at all, except in country roads. Within the boundaries of towns it is an absolute rule that no posts can be fixed in the streets. If we want posts we must put them in people's back gardens and in vacant lots, etc. Of course this has required that the majority of posts be placed on the tops of the houses. In foreign towns they have also had to go on the tops of the houses very largely. They have adopted one construction; we have adopted another. On the Continent most of the roofs have a very steep slope, and are tiled so that it is quite impossible to walk on them, and, of course, people do not put up stronger roofs than they can help—only strong enough to support the tiles and stand the wind, but not strong enough to support telephone posts. On such buildings they use two long pieces of timber, and form what they call a horse. That con-

sists of a number of uprights and a lot of cross frames. I think you have some of them here. Nearly the whole of the work is done in that way. In England we went to work in quite a different way. As Mr. Lockwood said, it is not unusual in London, at any rate, in overhead work on houses, to have wires arranged horizontally. As a rule there is but a single span. We have first of all what we call a chair. That is an iron casting weighing from fifty to sixty pounds that goes on the top of the roof. From this rises a wrought-iron tubular pole. These tubes are carefully made to specification; they are about three inches internal diameter. It is usual to put up a pole of not less than 18 feet, but they range as high as thirty. In such cases as the latter, it is usual to have two or three poles, one inside the other, each pole having a collar and a bolt going through. These poles are simply stayed to the brickwork. Heavy spikes are driven into the brickwork, and it is rather an agonizing process for the house as you may imagine, but somehow men have a way of doing it, and they drive spikes eight inches long into the brickwork. It is wonderful how the masonry stands it. I may say I have seen some very large cracks occasionally. The wall itself will sometimes split out in the plaster joint. Each pole will have at least four of those stays under ordinary circumstances, and then of course it has to be stayed in accordance with the rules.

When I came to America and saw the mass of wires running in all directions, it reminded me of what we call the early days of telephones in London, and we had so many faults with wires then that I could not understand how things worked. So I looked about me and I find apparently the difference is that we think nothing of a span of 120 yards. Sometimes in telephone work we go 200 yards, and 150 yards is considered very little for a span of wires. Of course in running wires that distance there is a very considerable amount of sagging, and in a wind they are liable to come in contact with each other, and they are also apt to get out of regulation; that is, wires put in when the weather is hot, and wires put in when it is cold, and brought into unison, will get out of unison occasionally. So that, perhaps, accounts for the reason why you are able to run such a mass of wires about the streets and yet get along at all.

Then we come to another point, what we call "leading in"—that is, taking the wire from the pole to the office of the sub-

scriber. In England that is always done with gutta-percha covered, wire, as the people who began telephone work in England were those who had had experience with telegraphs. This wire costs about three or four pence a yard. It has a thick covering of first-class gutta-percha. Of course this insures immunity from faults and leakage, and it is in some cases taped and in some cases braided. But if it is taped, it is very strongly taped, and the whole thing is what you call a very excellent job.

One very great reason why tramways perhaps have not made more advance in England is that posts are not allowed in the streets. Perhaps in the country districts they might be allowed, but without a lot of formalities, etc., before town councils, no leave to put up posts will be given. I think it is highly probable it will come, but still it will take time. On the other hand, notwithstanding what has been said about electric railways here, I know perfectly well you have nearly a thousand miles in operation. I have just come from San Francisco, and stopped there some days. I stopped at Denver and Salt Lake City, and at Chicago, and at Pittsburgh, and at Philadelphia, and I have been here some days. At each of these places I have done all I could to see electric tramway work. I happened to see a car in the distance at Salt Lake City. They were putting up the wires in Pittsburgh. I was kindly shown a car running with accumulators here yesterday. I called on the Sprague Company, and they said they had nothing which they could show within a hundred miles of New York, so that although you have a great deal, yet your country is so large, and the work is so scattered around, that it does not show much, and I think, perhaps, the same applies to England. We certainly haven't got anything like that length of track, but there are a lot of little tramways running about there which I think may be called to some extent the pioneers of tramway work. For instance, there is the Blackpool tramway, which has been running several years. There is the Portrush tramway, in the north of Ireland, which I think was the first electrical tramway ever erected. There is a small tramway running along the Brighton Beach which has been very popular and has been running six years. There are two or three companies in England operating experimental lines now in a small way, and certainly without going out of your way to see them you probably would not succeed in doing so.

Passing on to electric lighting, beginning at the station, at the

Grosvenor, we were working with 2,500 volts, and the dynamos were so perfectly self-regulating, at the period I was there, and with the load they had on them, that all regulating appliances were practically unnecessary beyond a sensitive governor on the engine and perhaps an electric governor on the engine and something to keep the exciter in order. All you have to do is to keep your dynamo turning round at the same rate. The circuits were so large that the putting on of lights or taking them off practically made no difference, and we always arranged things in such a way, that we never allowed, if we could possibly prevent it, any large circuits to be run into public buildings or theatres, or anything like that. That is to say, we always contrived that not more than 50 or 60 lamps should be turned off at the same time. Of course a man going around a building could turn off four or five switches, but while he was doing that the engine driver would have a chance to look around. The circuits were so large that 50 or 60 lights on or off practically made no difference, and most of the regulation was simply done by the engine driver controlling his engine. Of course that simplified matters very much.

The overhead work is done on very much the same line as telephone work, only the poles are shorter; sometimes they are not more than twelve feet, but as a rule they run to eighteen feet. Near the top of the pole is a clip, and an insulator is secured to this by a strap and nut, as was formerly done in telephone work. From here to the next pole, which might be as much as 100 yards away, but preferably not more than 60 or 70, a steel suspender of seven No. 14 gauge wires is run, and that is bolted up pretty tight. I might say it is a very difficult task, making up these steel suspenders—turning the things around to make a good tight way-leave job. Below this there was another similar insulator and to this the cable was made fast. The cable ran below the suspender. Most of the main circuit cables were nineteen No. 15 gauge, the branches being about seven No. 16's, and so leading off to seven No. 20's, or something like that for a few lights. You will see that, first of all, this steel suspender is absolutely insulated. That suspender will practically stand almost any voltage you could put on it. The cable itself was insulated in the same way. Supposing it was a bare wire there was always three inches of china between it and the nearest earth. These cables were first of all insulated with little ebonite

rings, by which they were suspended, having a little split ring which allowed them to run along the suspender. Afterward Mr. Ferranti adopted raw hide leather thongs, which were slipped over the cable. The cable was all wound up on a barrel or any convenient means. This cable was taken up to the pole, the first ring put on and the cart taken to the next pole. If you were going to run half a mile of cable you would have a man to almost every pole. They would haul the cable, the men putting on the rings as it went by. Of course it is a slow process, but it is fairly satisfactory when it is done. First of all, you have the insulation of the cable; secondly, you have the insulation due to the raw hide thong; thirdly, you have the insulation due to the suspender; so that altogether you are fairly safe. Supposing that suspender goes; the cable at first is bound round the insulator quite firmly enough. It is no use spending a lot of money on insulation and getting tests in a test room if you spoil it before it is up. But in this case these insulations were due to the cable that was wound around them and lapped across so as to avoid as far as possible cracking the insulation in any way. Therefore, unless the pole came down bodily, there was not much chance of an accident happening, and if the pole came down bodily, this insulation, as has proved to be the case in more than one instance, would be quite sufficient to keep everything right until the fault was remedied. There is another advantage in having this suspender. Our poles were usually lower than telephone poles. The steel suspender the telephone people were at liberty to draw their wires across as much as they liked. Occasionally they would get a wire underneath, and when it was sagged, haul it a few minutes, but they soon learned to leave off doing that. Of course, working with the alternating current and on a parallel system we have no confusion of wires such as there is here. A single circuit was generally sufficient for most of the requirements. In a few instances, where lines were going into different districts, owing to difficulties in getting our way-leaves, there might be four wires, but no more. I put it to American engineers whether this is not really the better way of doing things. The number of circuits you may get by running arc lamps, or anything else, in series becomes in time stupendous; and I know in working in telephone work underground what a bother it is to be mixed up with conduits and the remedying of faults. In adopting a parallel system you get rid of that, and

you get simplicity right away. When we wanted to take the current off we put another of these brasses on and another set of insulators and we took what we called "T's" out of the cable at a few feet from the post. These, of course, were small wires; they were carried down the side of the house, the insulators standing well out from the wall, and as a rule they went through the walls in china pipes, especially made for the purpose; that is to say, we do not simply take a chisel and ram a hole through a wall anyhow and just put the wires through, as I saw them doing in Pittsburgh. It was rather a costly job, I must say. We finished up with Portland cement afterward, the wire coming to a cut-out, which by the regulations of the fire insurance companies was either put on slate or on a brick wall. These wires were not allowed to be put on wood or near wood. Such things were not allowed as bringing a wire through the framework of a window. That would not be tolerated. When they come inside they come almost immediately to the cut-out, and even if there happened to be a ceiling three feet above, the fire insurance companies insisted on a large sheet of asbestos being fixed against that. From there we box our converters inside of iron bricks which were fixed in the wall, and on the way to the converter there was the usual switch for cutting the whole installation out. Of course the switch was in many cases not used at all by the householder. In fact, it was more for the convenience of the central station people than for the householder. They turn off their lamps on the local circuits.

Now, before going further, I would say something of the class of wire that was used. I think the reason that English work has taken the particular line it has, is almost entirely due to the fact mentioned by Mr. Lockwood, that England has done all the cable work so far. We were accustomed to expensive wire for cable work, and consequently we did not object to paying £250 a mile for such a cable as nineteen 15's, which I dare say you would think a good deal here. The class of conductor we used was made of nineteen No. 15's, tinned on the outside. This was then wrapped round with three wrappings of fine rubber, such as you use in making joints. Then on the top of that comes what is called a white rubber, that is wrapped on two or three times spirally; outside of that there is another of what is called black rubber. These two outside rubbers have vulcanized material mixed with them. When that cable is made

to the thickness of insulation which we used on these cables, and do use now—one-eighth of an inch of rubber—the cable is then put in the tank and vulcanized. Now, there is one point that cannot be too strongly insisted on, and which is this, that it is no use having an expensive cable like that if you are not going to protect it thoroughly. India rubber will stand fairly well under water. It will stand fairly well in moist weather, but will not stand in dry air; and it will not stand in alternations of wet and dry. If you will expose the rubber to the air it will in time perish. It is also liable, if it rests on anything sharp or sharply rounded, to get very thin at that point.

The way we went to work was this: On the outside of that cable is a fine waterproof tape, which is vulcanized on to the material and absolutely forms part of it. How much further you go depends on circumstances, but a general rule was to take a compounded tape, that is a strong linen tape twilled and dipped in some compound of ozokerite, and this was wrapped around in one or two coatings. Outside of that we carefully put on a strong braid of yarn, and the whole was thoroughly saturated with the compound. You have then done about all you can do, and I may say that in London I believe that there are three or four miles of cable of that class which has now been lying in iron pipes carrying a tension of 2,500 volts without any accidents. The cables are simply drawn into the iron pipes and lie side by side. I know that the Silvertown people four or five years ago laid down such cables as that for arc lighting throughout their works. The grounds of their works are fairly saturated with various mixtures, yet it has given them no trouble at all since. I cannot help thinking that if your cable is properly protected that it will not give trouble. That cable, of course, before it leaves the manufacturer, is carefully tested. I have spent months in testing telephone and electric light cables of that character. This class of cable manufactured by the Silvertown Company would test from 2,000 to 8,000 megohms to the mile at a temperature of 75°. If you put the testing current on to a cable like that it flows into the cable with a great rush, and then the rush diminishes, and you gradually see the spot of light coming back. One should always watch that spot of light for ten minutes. Sometimes it will give a little kick, and that will denote that something is not quite right. But the Silvertown people have told me, and I have known, that they have manufactured in submarine

cables as many as seventy miles of cable without locating any fault that they were obliged to cut out.

As to installation work, that is also done with first class rubber covering thoroughly vulcanized. It usually depends a good deal on the fire insurance inspector. One man will pass one thing and another will not pass it. You have got to know your man. Mr. Musgrave Heaphy first succeeded in imposing his rules more or less generally, and work is now, I believe, fairly up to his standard. His standard means that no wires are to be within an inch of each other in wood casing; that wood casing is used everywhere; that there is no exposed wire; that there are cut-outs to every two or three lamps; that the cut-outs have all slate or porcelain bases; that all switches have porcelain solid bases, and that no screws communicating with the current are allowed to come in contact with woodwork at all.

No doubt we have sacrificed rapidity of progress to some extent, and we have had a lot of trouble; still there has been immunity from accidents, which is very gratifying, and the work will stand. There is no doubt that the people, when they put electric lights in their houses, have an idea that it is going in just the same as gas fittings, but a good deal of the electric work put in in past years I do not think would last as long as fair average plumbing. I am very much obliged to you for listening so appreciatively.

THE CHAIRMAN:—I would like to ask Mr. Addenbrooke his opinion on the proposition which we have heard considerably of within a few weeks, that while there is no particular difficulty in insulating a direct current of 3,000 or 4,000 volts, it is absolutely and entirely impossible by any known means of insulation to insulate an alternating current of a thousand volts. What is your experience as to that?

MR. ADDENBROOKE:—It is not a subject on which one likes to make a random shot—and my experience was pretty fully stated in the *London Electrical Review* three or four years ago. I do not think there is anything whatever to show that the alternating current will break down insulation quicker than a continuous current. I know a great many statements are made on the subject. I do not know of any one in England or America who has made a careful series of experiments on that point. We all know that the alternating current will not produce anything like the arc that the continuous current will.

A continuous current of a thousand volts will produce an arc—I would not like to say how much longer than an alternating current will produce. We know that a cable does not receive the full charge of electricity at once, while you can see the movement of the galvanometer an hour after the cable has had the current on, but of course the great rush occurs immediately. Still it takes a very appreciable time, and in the case of an alternating current, we will say alternating 200 times a second, it is quite conceivable—I do not say that it is a fact, but it is worth putting forward—that the insulating substance around that cable has not time to get sufficiently polarized to allow the discharge to pass through quickly before the current has turned in another direction and has depolarized it. I do not say that this is a correct view. It is a thing that requires to be gone through very carefully. From all the observations I have made and what I have heard on the question of insulation, I think that an alternating current will not go through more quickly than a continuous current.

THE CHAIRMAN:—The English telegraphic engineers have always taken the ground that a submarine cable was less injured by an alternating than by a continuous current. They have used the double current system on defective cables, in preference to the single current system, which will tend to prove, I suppose, that they apprehended more trouble from the breaking down of the insulation by the continuous current than by the alternating.

MR. LOCKWOOD:—The hour is late, so I shall make my remarks in reply to questions very brief. The Secretary has mentioned the subject of pneumatic tubes, and that very little or nothing had been said in my paper regarding them. I think, perhaps, I may be excused for the reason that there was very little or nothing to say. It is true that pneumatic tubes are much more extensively used by the British telegraph authorities than they are used here, because it is apparently one of the maxims of the British telegraph authorities that it takes a longer time to deliver a message than it does to send it. I am sure that the same view is borne out by the experience of every one of us who has ever had occasion to send or receive a despatch, and so instead of filling up the large cities such as London, Liverpool, Manchester and Birmingham with telegraph sub-offices, at about every hotel and every ten blocks, they have organized a system of pneumatic tubes which is very like that of the Western Union in New

York, but on a much larger scale, and as a general thing, they send their messages in packages in a pneumatic tube from one point to another.

In respect to the inquiry made by Mr. Garratt concerning the relative methods of inside construction in electric lighting, and how they get along there with the inspectors, I think that has been sufficiently answered by Mr. Addenbrooke.

Mr. Martin thought something should have been said regarding the electric motor railway service. There are not anything like as many street car roads as there are on this side. But it is only within the last twenty-five years that street car railways were introduced into England by Citizen George Francis Train, and they called them train roads, not from any connection with Mr. Train, but because there were train roads in collieries, before Mr. Train was heard of. During the twenty-four years I was absent from England, I found there had been a great advance in street railroad business. But they are not a fast nation. In England they would rather do a thing well once than do it fast a dozen times. So they found the horse car a pretty good thing to stick to, and they have made more of it than we have done, because they make all the cars double deckers; not only that, but they use steam dummies to a very large extent, and between Birmingham and Soho and other districts I find they use the traction cables, and it gives good service. One of the electric roads I had the pleasure of traveling on was about a couple of miles long, and situated on Brighton Beach. It is a very poor kind of a thing to look at, but it is in a safe location—on the sands of the sea shore, and it does not trouble a single telephone wire. The current passes through the two rails. The Port Rush road is still there, and, as I understand, is doing good service. I had not time to see it. After all is said and done, the main reason that electric motor roads, operated as we operate them with a single wire overhead are not more common, is the reason mentioned by Mr. Addenbrooke, reinforced by the very potent hand of the central government which knows that the operation of such an electric railway in such a way would be a great deal of a nuisance to its own telegraph wires, and would mean death and destruction to all telephone wires in the kingdom, which will possibly be all government property some day. I asked Mr. Preece about that, and he reminded me that he had presented to the Institution of Electrical Engineers a paper

showing very clearly the evil results to all electric systems operating sensitive instruments, of railway or electric light systems using the earth for a return. I also inquired of a gentleman well informed in electrical matters, why the electrical railways were not more used with the overhead wire, and he said because they would not be allowed. I thought that was a very good, solid reason, and when I told them how they were being sown broadcast through the land here, and how, when harmless telephone companies remonstrated, they were universally met with the cry that the telephone companies wanted the earth, he said, "That is very true; they want the earth here also, but they want it to work on like any other peaceable mortals, and they do not propose to allow that a tiger has the same right to walk the earth that a man has." And that seems to me the principal reason why the electric railway has not made more progress than it has in England.

I do not know that I have anything more to add except to express my gratification at the very lucid demonstration made by Mr. Addenbrooke. He said one or two things that I should like to have said myself, but I am going to stay in the country and he is not. I thank you, gentlemen, for your very kind attention.

THE CHAIRMAN:—In closing this very interesting discussion, I will take the liberty of expressing the thanks of the meeting to Mr. Addenbrooke for the information he has given us, and will announce that the next paper before the Institute will be read on the evening of October 29th, by our fellow member, George B. Prescott, Jr. His subject is "Some Methods of Regulating Accumulators in Electric Lighting."

SOME METHODS OF REGULATING ACCUMULATORS IN ELECTRIC LIGHTING.

BY GEORGE B. PRESCOTT, JR.

IN preparing the following paper, the limited scope of which is indicated by its title, I have assumed that it is generally conceded that the modern electric accumulator is an apparatus capable of performing a peculiar but useful function in the art of electric lighting as now commercially practiced, and that it is free from inherent defects which would render it unsuitable for such application. Indeed, I am sure that every careful observer has noted in the somewhat slow evolution of the accumulator, that structural improvement and adaptation to practical requirements, which unquestionably show that it has come to stay; and will acknowledge that even as it exists to-day, the accumulator is a factor in electrical industry too important to be ignored by those who take a broad view of the situation.

It is not my intention to refer to those numerous successful applications of accumulators to the propulsion of small marine vessels and land vehicles, to car lighting and other minor work where the continuous generation of power from the combustion of fuel would be impracticable; neither can I fully discuss their characteristic actions under working conditions, within the limits of this paper. Nevertheless, before proceeding to the subject proper, I deem it incumbent to point out that the electrical accumulator, even in its more improved forms, is an apparatus having well defined limits of capacity, and that these limits cannot be habitually exceeded without endangering its effectiveness and impairing its durability. Generally speaking, the limits referred to, which vary with every type and size of cell, relate to the rate and quantity of charge and discharge,

these factors being measured respectively in amperes and ampere hours.

In considering this admission, however, it should not be forgotten that every dynamo-electric machine is, to a certain extent, subject to similar limitations; for, like the accumulator, if it is demanded of them, they are capable of generating a current far exceeding their safe carrying capacity. Here the likeness ceases, however, for while the dynamo will deliver its normal current as long as adequate power is applied to its shaft; by continuing to draw current from an accumulator for too long a time, as likewise from an excessive rate and quantity of charge, serious damage may result. In fact, in some respects an accumulator may be likened to a draught animal, which can be made to perform abnormally large amounts of work for short periods of time, but only at the expense of its vitality if the practice is frequent.

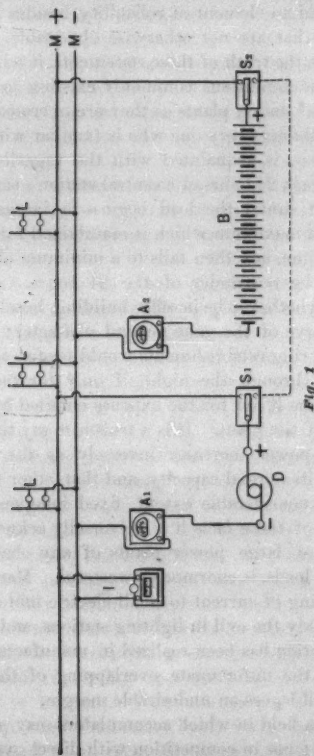
While much might be said regarding the maintenance of accumulators, and moreover, the apparatus to be presently described is employed in a large measure for the purpose of effecting proper maintenance as well as regulation, it must suffice to say here that the normal working rate and capacity of an accumulator battery having been stated by the makers, all necessary data relating to its use may be ascertained from the indications of ordinary hydrometers, ammeters and voltmeters. That is to say, during the charge and discharge of such a battery the rise and fall of its potential and of the specific gravity of the electrolyte in its cells, are both quantitatively indicative of its condition and capacity for doing work. It is evident from what has already been said regarding the importance of working accumulators within certain prescribed limits, that in order to effect this result two classes of apparatus must be provided with every accumulator installation, viz.:—indicating or measuring instruments, and regulating appliances to be operated either automatically or by hand. I am constrained to add here, that careful and extended observation leads me to believe that a lack of appreciation of those now obvious facts will largely account for the ill success attending many of the earlier accumulator installations.

Although there is reason for believing that some of the early promoters of business enterprises based on the manufacture of electrical accumulators, anticipated that accumulator systems of

lighting were destined to compete with and perhaps supersede many direct systems, I believe that the more mature modern idea is that they are, for the present at least, mainly subsidiary to other electric lighting systems. As auxiliaries to many direct systems, accumulators undoubtedly effect a reduction in running expenses and add an element of reliability, besides accomplishing certain results that are not otherwise obtainable. In order to fully appreciate the truth of these statements, it will be necessary to glance at the conditions commonly existing in ordinary isolated and central station plants as they are operated at the present time. Doubtless every one who is familiar with the electric lighting business, is acquainted with the vagaries of the load curves during each 24 hours of a central station's run. Generally speaking, about sunset the load begins to increase gradually, finally reaches a maximum which is maintained for a greater or less period of time, and then falls to a minimum about which it fluctuates for the remainder of the 24 hours. Almost every isolated plant, whether it be in office building, hotel or apartment house, has a curve of the same general character; and probably most manufacturing establishments would prefer to have a few lights burning through the night, if only for the watchman's convenience, were it not for the expense entailed by the continuous operation of the plant. It is a truism to say that the cost of fuel per horse-power increases inversely as the power plant operates below its normal capacity, and that other operating expenses are, to a considerable extent, fixed independently of the load. In view of these facts it is universally acknowledged that the operation of large power plants of any character during periods of light loads, is enormously wasteful. Many have hoped that the supplying of current to small electric motors during the day would remedy the evil in lighting stations, and to some extent the expectation has been realized in manufacturing centres, but even here the unfortunate overlapping of the motor and lamp service still leaves an undesirable margin.

Here then is a field in which accumulators may perform their special function; not in competition with direct systems, but as supplying the missing feature in the commercially successful operation of most 24 hour plants of moderate size. There is no obstacle in the way of applying a sufficient number of accumulators to a plant of the character mentioned, to maintain the light load during the time it would not pay to operate the power

plant, and to provide for the charging of the accumulators during the regular running time of the dynamos. Assuming, in illustration of this statement, that 10 hours is the ordinary working day, and that the engines of a central lighting station are started at 2 P. M. and are operated until midnight, it is probable, if not



certain, that there will be sufficient surplus current for an ample length of time, to charge enough accumulators for the service required after the engines cease to revolve; excluding, of course, the period of maximum load, when the dynamos will be taxed to their full capacity in their regular service. Under such con-

ditions the engines could be operated at somewhere near their normal capacity during the whole period of their running time, and the cost of unit power would be a minimum; while only one staff of men will be required. It may be advisable to explain here that although the current available for charging the batteries during the regular running time of the dynamos would vary with the lamp load, this is of no importance as it is not essential that the batteries should be charged at a uniform rate. In the case of such stations as also supply arc lights, the engines could be started later and operated through the night. Besides reducing the operating expenses of a station during its periods of light load to a greater extent than they increase them at other times, in the event of an accident to the power plant or incandescent dynamos, the accumulators can always be called upon for extra service; while whenever there is an abnormally heavy demand for current they may also be operated in conjunction with the dynamos.

But there is still another field in which accumulators may be employed to equal advantage, viz.—that of long-distance light-



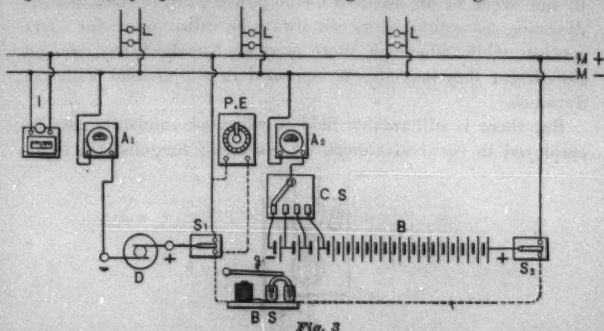
Fig. 9

ing now so successfully occupied by the alternator-converter system. An accumulator is indeed merely a chemical converter, which is unequalled as a pressure-reducer, and any one who gives careful thought to the subject will perceive what an excellent substitute it is for the alternator-converter in those situations where the character of the lighting makes it necessary to run "light" for many hours each day. Indeed I can only account for the fact that accumulators were not long since more extensively used for this class of lighting, except by the existence of a feeling of skepticism as to their durability, together with their somewhat formidable first cost.

As manufacturers now guarantee the durability of accumulators, under certain conditions of use, for an annual percentage on their first cost; and as methods of manufacture must improve with experience and moderate that cost, both of these objections are gradually being modified.

But even in the present state of the art, the question of first cost, depreciation and efficiency may be duly allowed for, and a considerable reduction in operating expenses still shown to result from the use of accumulators under many circumstances. To quote from an article by the writer "On the Place of Accumulators in Electric Lighting," which was published in the March issue of *The Electrical Engineer* :—

"Whenever one kind of energy is transformed into another kind, more or less loss can be shown to occur, and the action of the accumulator is not an exception to this rule. The proportion of loss generally varies with the conditions under which the transformation is effected, and in the case of the accumulator depends mainly upon the rate of charge and discharge. If these



double transformations are conducted slowly the loss may be nearly inappreciable, but at the higher rates which are frequently demanded in practice the efficiency is proportionately reduced. The fact of the existence of this loss clearly indicates that the direct production and consumption of electricity must always be less expensive, both in original outlay and cost of production, than its subsequent use through the medium of accumulators; unless, indeed, there are other modifying conditions which overbalance the additional cost of accumulators and offset their maintenance. That such conditions do exist in many branches of the electric lighting industry can be readily demonstrated, and it may likewise be shown that the use of accumulators as auxiliaries to many existing lighting plants would insure a marked reduction in their running expenses.

"From what has already been said regarding the infallible certainty of loss resulting from any form of conversion of energy, it is evident that if the load were equal to the capacity of a plant for 24 hours each day no system of conversion could compete in point of economy with one which effected the direct production and use of the current. There is an exception even to this general statement, however, when one or more groups of lamps are located at such a great distance from the source of power that the interest on the cost of conductors, together with the cost of the energy wasted in them, becomes of serious importance: not to mention the increased difficulties of regulation. In cases of this character, the value of the accumulator as an auxiliary to a direct



Fig. 4.

incandescent system becomes obvious. The cells may be located directly at the centres of consumption and charged by a moderate current at high pressure over a small conductor. They may be charged during the hours of light load and discharged as required, the whole charging current, in addition to the current of the batteries, being available on the lamp circuits, during the period of maximum load, if it should be so desired. Often the interest on the cost of such an accumulator installation, plus the cost of the energy lost in conversion of current, is much less than the loss by the direct system as previously specified. Another and vastly important consideration in favor of the accumulators is that during the 10 or 12 hours of each day when the consumption of current is so small that a station can only be operated at

a loss, the power could be shut off entirely and the accumulators resorted to for the current required during that period."

As a matter of fact, the ideal condition of a continuous maximum load, as assumed above, nowhere exists in practice. The actual load curves for stations of similar capacity throughout the country differ not only in respect to the duration of the maximum period, but likewise in the hours during which the light and heavy loads occur, according to the character of the lighting. It is nevertheless true that they all show a remarkable similarity in the variation of current consumption, and all the 24 hour stations, particularly the smaller ones, require but a very small por-

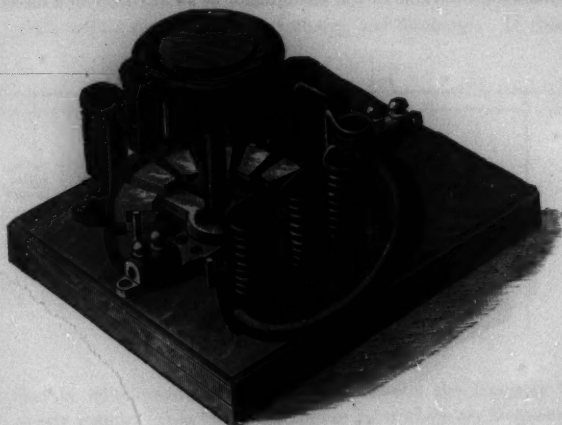


Fig. 5.

tion of the capacity of the plant for the greater part of the day. For this reason many of the smaller stations cannot be profitably operated for more than 12 hours a day, and customers are therefore unable to obtain the light for the remainder of the 24 hours, the system being thereby deprived of much of its value to many consumers.

Here again the utility of the accumulator for tiding over these costly periods of light loads becomes apparent. It is evident that any ordinary station running for 12 hours a day, more or less, is not likely to have an output approaching its capacity for more than two hours at the longest, while for the greater part of the time it will be much below it. Why should not such a

station be operated during that period of 12 hours at somewhere near its full capacity, and, therefore, under the most economical

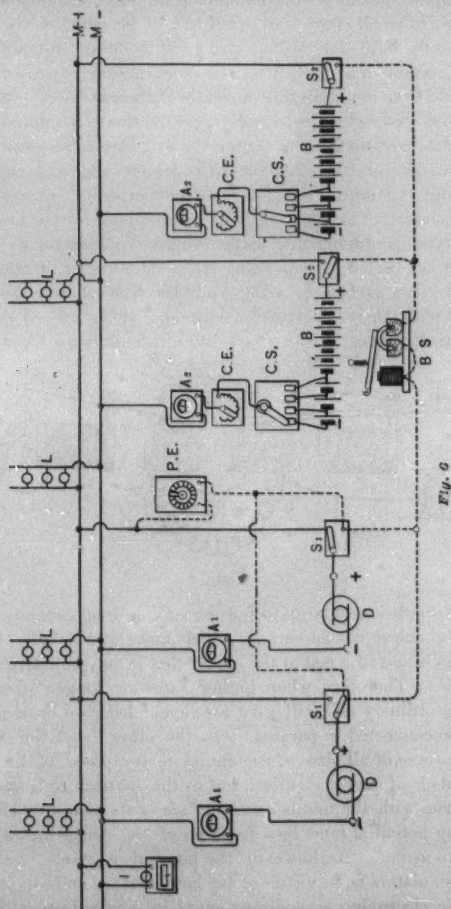


Fig. 6

conditions for the power produced, and utilize the excess of current to charge a sufficient number of accumulators to maintain the lighter load during the remainder of the day?

This is the legitimate work of accumulators, and when they are properly installed and maintained to meet such conditions, the class of small stations referred to will be enabled to supply satisfactory light for 24 hours a day at moderate cost, while the larger stations may greatly reduce their running expenses and at the same time maintain the efficiency of their service."

Before proceeding to consider the methods of regulating accumulator currents, it will be advisable to examine some of the peculiarities of the element with which we have to deal. Generally speaking, the total current capacity, expressed in ampere-hours, of a single cell of accumulator of the lead lead-oxide type, is proportional to the number and size of its plates; its rate of discharge depending upon the number of plates and the effective surface of each, while the time of such discharge varies with their thickness. Although there are no obvious theoretical reasons why a single cell of accumulator should not

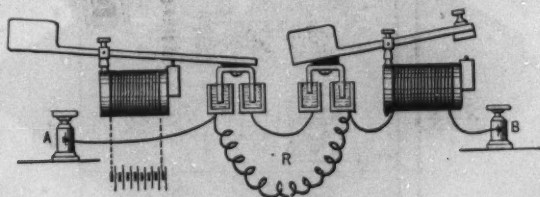


Fig. 7

be made sufficiently large to possess any desired capacity, there are mechanical considerations which make it advisable to limit the dimensions of a cell to the extent that it may be conveniently portable. Therefore when higher rates or longer discharges than an ordinary cell will give are demanded, two or more cells must be connected in parallel. On the other hand the electromotive force of all sizes of accumulators composed of the same elements is of course identical, but as the internal resistance of a cell varies with the number and surface of its plates, its effective working potential must be a function of the strength of the discharge current. As, however, the internal resistance of all sizes of accumulators is, in virtue of the large surface and compactness of their electrodes, exceedingly small in comparison with their rate of discharge, their working potential nearly equals their electromotive force on open circuit. While the normal effective

working potential of a fully charged accumulator in good condition is usually stated as about two volts, as a matter of fact it is somewhat higher than this after being charged and rather lower after normal discharge, the average effective potential being about 1.95 volts. During the operation of charging an accumulator, its potential, or what is then usually called its counter electromotive force, rises gradually until the cell is nearly charged, and then more suddenly as gas is evolved, sometimes requiring an effective charging pressure of as high as 2.5 volts per cell if the current is continued after the cell is charged. In actual practice the accumulator is usually considered to be fully charged

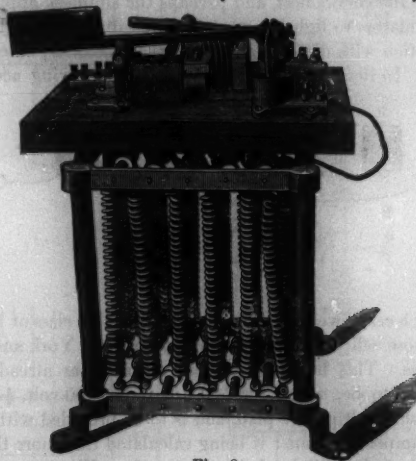


Fig. 8.

when the potential of the normal charging current reaches 2.3 volts per cell, or at 2.2 to 2.25 volts per cell when the charging rate is reduced as gas begins to be freely evolved towards the end. Similarly when a cell is discharged at the normal rate its effective potential falls during the progress of the discharge from 2 volts to 1.8 volts, at which latter point it is considered to be discharged to its normal limit.

The facts above cited to the effect that the electromotive force of accumulators rises during charge, and falls during discharge and that their capacity for charge and discharge is limited, are the key notes to the regulative processes; and only one other point

need be here considered. When two or more series of cells connected in parallel are to be charged at the same potential, it is evident that, unless each series is in precisely the same state in respect to residual charge, there will be a difference in their electromotive forces; and, in consequence, less current will flow in those series having higher potentials than others. While the larger current flowing into the less charged cells will have a tendency to bring up their potentials to the average, it is found in practice that some series will become fully charged sooner than others. The simple means provided for compensating for these variations will be duly described.

One of the commonest, and perhaps the simplest applications of accumulators to lighting work is found in their employment in connection with direct isolated plants in factories, office buildings, etc. In illustration of the method of applying accumula-

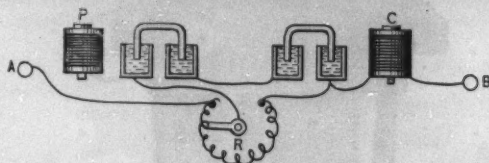
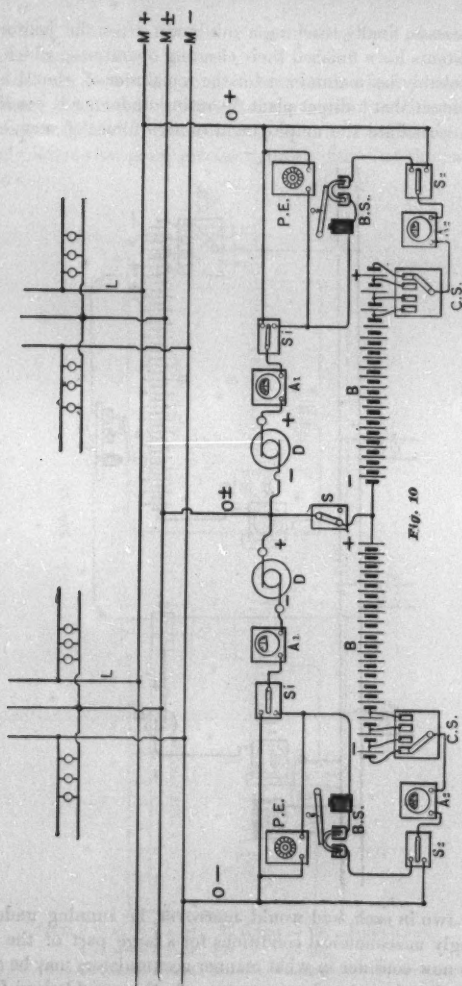


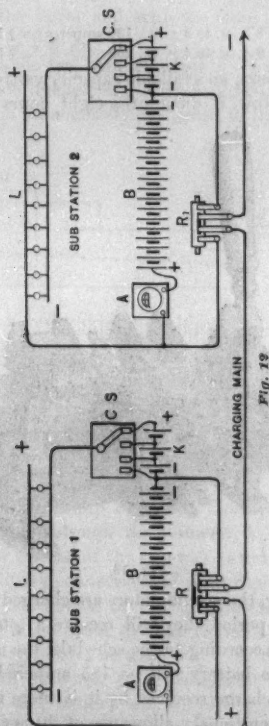
Fig. 2

tors in such cases, we may select as a type of this class of lighting one of those office buildings common in New York and other large cities. This building, we may assume, has already been, or is about to be, wired for 500 16-candle, 100-volt, $\frac{1}{4}$ -ampere lamps on the multiple-arc plan, and is to be provided with a 125-volt, 200-ampere dynamo; it being calculated that more than 400 lamps will rarely be lighted simultaneously. We are not specially concerned with the power plant, and will simply assume that it is of ample capacity, it being remembered that such buildings are usually steam heated, and therefore, offer favorable conditions for the operation of a plant of the character under consideration. Now it can be deduced from experience that, during the day, from say nine o'clock in the morning until about sunset, only a limited number of lights will be burned in certain dark corners of the building, and that as twilight and darkness come on the load will gradually increase, reaching a maximum at a certain hour depending upon the season; subsequently the load



of one staff of men and reducing the running time of the engine to eight hours.

It has been shown in a general way how the load varies during 24 hours ; but in order to ascertain the capacity of the accumulators required, it will be necessary to assume, though only approximately, somewhat more precise figures. Say that the load is as follows :—



From 9 P. M. to 9 A. M.,	20 lamps	—	180 ampere-hours.
" 9 A. M. to 4 P. M.,	200 "	—	700 " "
" 4 P. M. to 6 P. M.,	400 "	—	400 " "
" 6 P. M. to 9 P. M.,	50 "	—	75 " "

An inspection of the above schedule shows that for 12 hours out of the 24, only 20 lamps, or 10 amperes, are used, while for

three hours more only 50 lamps, or 25 amperes, are required; and a simple calculation proves that a set of accumulators having a capacity of 200 ampere-hours will be amply sufficient to maintain the light lamp load for 14 hours out of the 24. If the dynamo is started at 8 A. M. and operated until 6 P. M., while maintaining the required number of lamps during that period, it will still have surplus current for charging the battery as follows:—

From 8 A. M. to 9 A. M., 190 amperes for 1 hour,
" 9 A. M. to 4 P. M., 100 " " 7 hours,

or 890 ampere-hours, an available capacity vastly in excess of the requirements. Now, if during the eight hours in which the dy-

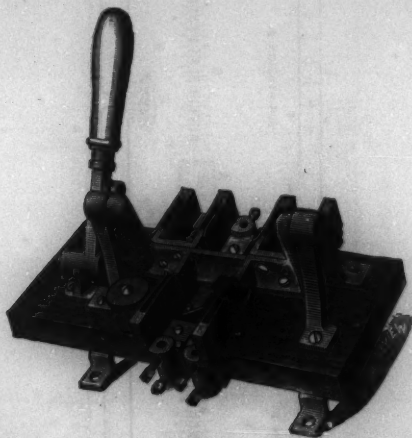


Fig. 13.

namo is operating, the accumulators are charged at the rate of 30 amperes, in that period they will receive a total charge of 240 ampere-hours. According to the schedule, the maximum output required from the battery will be 185 ampere-hours, whence it follows that the charge received by it is more than ample, even after making the customary allowance of 20 per cent. for loss by conversion; and the desired result has been accomplished.

We have now to consider the details pertaining to the practical arrangements of such an installation. According to the stipulated schedule, after the dynamo ceases to run at 6 P. M.,

the battery alone must supply 25 amperes for three hours, and thereafter 10 amperes for 11 hours, or a total output of 185 ampere-hours. One series of 50 cells, having say a normal capacity of 30 amperes for eight hours, will satisfy these requirements, and will be well within the nominal rating of ordinary commercial cells. Assuming that these 50 cells, connected in series, have been suitably placed on insulated shelving at any convenient distance from the dynamo, they may be electrically connected with the latter and with the lamp circuit, as shown diagrammatically in Fig. 1.

In this diagram the two parallel wires $M (+)$, and $M (-)$, represent the common dynamo and lamp mains to which the pressure indicator, I , is permanently connected in the usual manner :

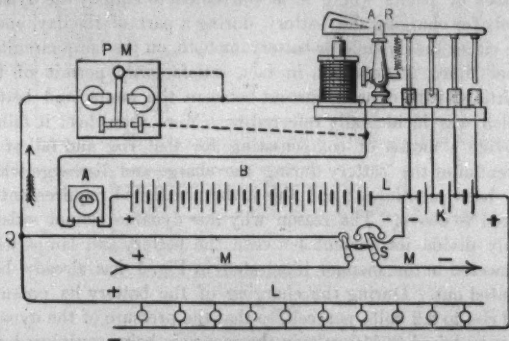


Fig. 14

and $L L L$ represent the lamp circuits. The dynamo, D , is connected to the mains through the ammeter, A_1 , on one side, and through the upper contact of the two-way switch, s_1 , on the other. These are the ordinary connections of a multiple arc plant; and the $(+)$ and $(-)$ terminals of the accumulator battery, B , are also connected with the mains through the ammeter, A_2 , and two-way switch, s_2 , in precisely the same way. It is evident that if the levers of both switches, s_1 , s_2 , are against their upper contacts, the dynamo and battery will supply current to the lamp circuits in exactly the same manner as would two dynamos connected in parallel, provided, of course, that they are both at the same potential. On the other hand, if the potential of the dynamo slightly exceeds that of the battery, the current from the

former will divide between the battery and the lamp circuit in a certain proportion determined by the ratio of the resistance of the lamp circuit to the internal resistance and counter electromotive force of the battery. If the levers of the two switches, s_1 , s_2 , are now moved to their lower contacts, the dynamo and battery will be connected in series with their like poles opposed, the main, m (—), acting as part of the circuit; and supposing that the pressure of the dynamo still exceeds that of the battery, the latter will receive a charge. Thus, by this very simple arrangement, the dynamo and the battery, either separately or together, may be connected with the lamp circuit, or with each other, or be entirely disconnected.

While this method satisfies all but one requirement in certain classes of plants where it is convenient to employ the dynamo solely for charging the battery during a part of the day, and to use either the dynamo or battery, or both, on the lamp circuits at other times, it does not, in fact, satisfactorily permit of that splitting of the dynamo current between the lamps and battery which was incidentally referred to. More than this: it fails to provide a means of compensating for that rise and fall of the potential of the battery during the charge and discharge which has been mentioned; and this is the unsatisfied requirement referred to above. The reason why the dynamo cannot satisfactorily divide its current between the battery and lamps when connected in the manner illustrated in Fig. 1 has already been pointed out. During the charging of the battery its potential will rise to 2.2 volts per cell, so that the pressure of the dynamo must be raised to 110 volts in the case now being considered, and this excessive pressure would endanger the life of the lamps. How, then, will it be possible to employ the higher pressure demanded by the battery and at the same time supply current to a number of lower voltage lamps without raising their candle-power above normal? The answer is easily given, for it is only necessary to insert a suitable resistance in the main between the dynamo and lamp circuits in order to accomplish the desired result. Such a resistance, usually called a "pressure equalizer," should be made of wire sufficiently large to safely carry the current for the greatest number of lamps likely to be required at the time when the dynamo which supplies them is to be simultaneously called upon to charge the battery, and should be made conveniently adjustable, as the fall of potential through it varies

with the current. The method of regulating the working potential of the battery is equally simple, for it merely consists in adding to, or subtracting from, the number of active cells in circuit. This is accomplished by means of a multiple-point switch, called a cell-regulating switch, shown diagrammatically in Fig. 2, which is so constructed that, in the act of shifting the cells in and out of circuit, it neither interrupts the circuit nor short-circuits the cells. It consists essentially of a single pivoted lever, which carries on its outer end a short metallic arm. This arm is attached to the lever by means of a block of insulating material, but is electrically connected with it by a short spiral of

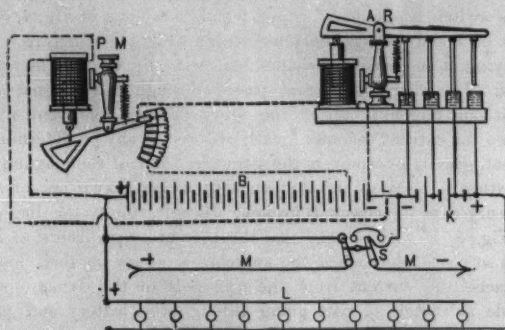


Fig. 15

german-silver wire. The lever and arm may be made to pass over a number of contact strips, which are so arranged that before the lever breaks contact at one strip, the arm comes in contact with the next strip, and the reverse action takes place when the lever is moved in the opposite direction. During the brief interval while both lever and bar are in contact with adjacent strips the cell connected to those strips discharges a feeble current through the spiral of wire.

It is necessary to mention here, that in practice it is customary to provide for the installation of 10 per cent. more cells in each series, than a simple calculation on the basis of two volts per cell would show to be necessary. Thus a plant using 100 volt lamps would require $100 \div 2 = 50$ cells + 10 per cent. of 50 = 5, or 55 cells in each series. This allowance is usually sufficient to

compensate for the fall of potential during discharge, as well as to provide for the ordinary loss of potential in the lamp mains.

The method of employing the pressure equalizer and cell-regulating switch is shown in Fig. 3, this diagram being otherwise similar to Fig. 1, with the further exception that an automatic break switch, πs , is inserted in the branch wire connecting the dynamo and battery through the lower contacts of the switches s_1, s_2 . The function of the automatic break switch is merely to interrupt the charging current, in the event of the potential of the dynamo becoming so much reduced from any cause as to allow the battery to overcome it, and perhaps reverse its polarity. This switch, a practical form of which is shown in Fig. 4, consists of a simple electro-magnet with a weighted armature lever carrying at one end an Ω -shaped bent wire dipping into mercury cups. The charging current passes through this magnet and from one mercury cup to the other through the bent wire. When the current becomes greatly reduced to any predetermined extent, gravity overpowers the attractive force of the magnet, its armature is released and the bent wire being drawn out of the mercury cups the circuit is broken. By referring to the diagram in Fig. 3, it will be seen that the pressure equalizer, $p k$, has been so placed that when the switches s_1, s_2 are on their lower contacts, the current from the (+) pole of the dynamo will divide at switch s_1 , part going through the battery and part through the pressure equalizer to the lamp circuits, both currents again uniting at the main, π (—), to return to the (—) pole of the dynamo. By this arrangement the potential of the dynamo may be adjusted to the requirements of the battery, and at the same time the pressure at the lamps suitably reduced by adjusting the resistance of the pressure equalizer.

When the proper balance is once obtained, and by means of this apparatus it may be quickly and easily accomplished by one man, no further attention than would ordinarily be given to the dynamo would be necessary, for although the counter potential of the battery would gradually rise toward the end of the charge and the current passing into the battery become correspondingly reduced, this result is even desirable, as it is somewhat advantageous to reduce the strength of the charging current as the battery becomes filled. In some installations, however, the extra or regulating cells are used to a more limited extent than the others, and thus having had less current taken from them they

become sufficiently charged in a shorter time. A simple movement of the cell-regulating switch will then serve to cut out of circuit one or more of the charged cells as may be required, while the others receive current for a longer time. In some cases a further adjustment of the field rheostat of the dynamo and of the pressure equalizer may afterwards be required, and if so are quickly effected.

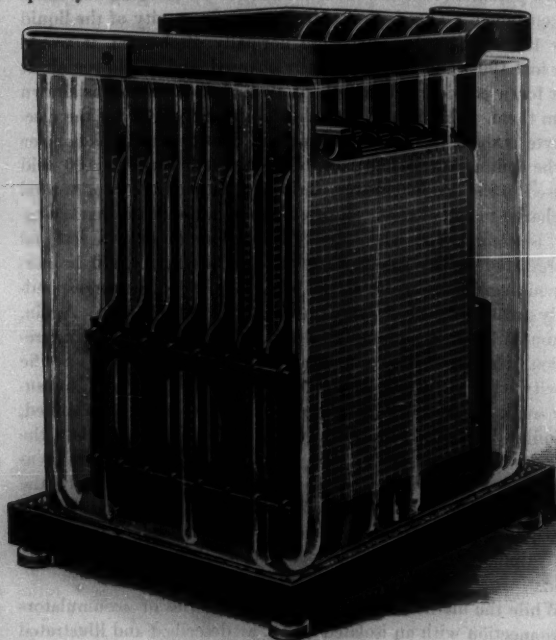


Fig. 16.

The first indication that the cells have received nearly enough charge will be given by the gentle evolution of gas which gradually increases thereafter, and which should never be allowed to become violent. At the same time the potential of the battery will approach 2.2 volts per cell, and even reach above 2.3 volts per cell when the gassing becomes marked. In order to take advantage of this indication of charge it will be sufficient to have

a voltmeter conveniently located, and connected with the terminals of the battery, by means of which instrument, the number of cells in the battery being known, the potential per cell is readily ascertained. While this increase in potential is taking place, a similar variation in the density or specific gravity of the electrolyte in the cells also occurs, but this change, unlike that of the potential, remains fixed, even after the charging current is discontinued. That is to say, if the specific gravity of the liquid was 1.160 when the cells were normally discharged, it would rise to 1.190 when they were fully charged, and would remain at that for a considerable length of time if no current was drawn from them. This rise of 0.030 in the specific gravity of the electrolyte is about the average increase in density which takes place in the common types and sizes of accumulators when 1.160 acid is used in the original charge, and when the range is from normal discharge to full charge. It often happens, however, that charging is commenced when the cells have more or less residual charge, and in this case the rise in specific gravity will be correspondingly less; while on the other hand it will be correspondingly greater if the cells were previously over-discharged. Again, if unusually large containing cells enclose the piles (as the aggregation of electrodes is commonly designated) the rise of specific gravity will be smaller, and on the other hand, larger if unusually small containing cells are employed. As heretofore stated, a similar drop in specific gravity and potential occurs when the cells are discharged, which in degree has about the same value as the rise. This variation in specific gravity is explained by the formation of lead sulphate during discharge, which implies the absorption of acid from the electrolyte, and by the reduction of this sulphate during the charge when the electrolyte is strengthened.

While the method of installing a single series of accumulators in connection with an isolated plant, as described and illustrated in Fig. 3, fulfils most of the conditions required in small plants operating a single dynamo, in larger plants of a similar type using two or more dynamos, several series of the largest cells may be required. Although such an installation would consist mainly of an amplification of the system already described, still there exists a new difficulty not met with in that system. This arises from the fact already mentioned, that when several series of cells are charged in parallel, any essential difference in the amount of the

residual charge in the several series, results in their allowing different amounts of current to flow through them, although all of the series are charged at the same potential. The remedy for this undesirable result is of the same character as that employed to prevent excessive pressure on the lamp circuits, when the dynamo which supplies them with current is at the same time used to charge accumulators. In circuit with each series of cells is placed a small adjustable resistance coil, called a current equal-

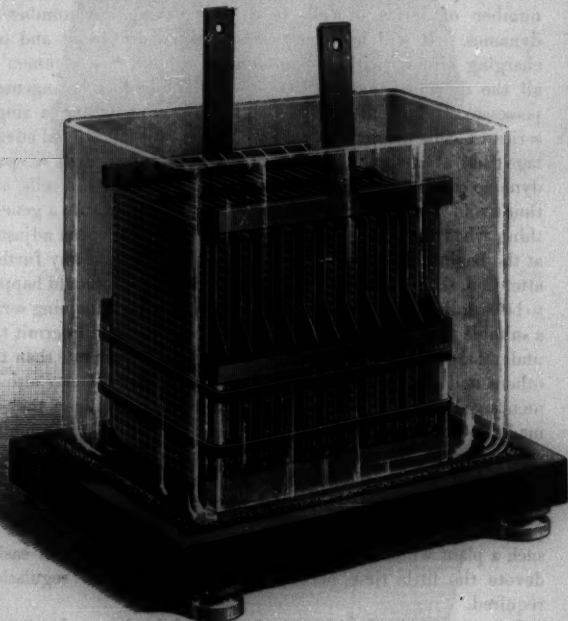


Fig. 17.

izer, a cheap practical form of which is shown in Fig. 5. It is composed of wire large enough to carry the maximum current of a single series of cells, and usually has a resistance of from $\frac{1}{16}$ to $\frac{1}{8}$ of an ohm. Each series of cells is also provided with an ammeter, and upon the commencement of a charge the current equalizers are so adjusted that each ammeter shows the same

amount of current to be passing through each series. In order to avoid as much as possible any loss of energy in the current equalizers, they are all turned to the non-resistance point at the start, and resistance is then only inserted in such series as may be taking more current than others.

The general arrangement of an accumulator plant consisting of two dynamos and two sets of batteries is illustrated in Fig. 6, and a simple extension of this plan only is necessary to adapt any number of series of cells to a plant having any number of dynamos. It will be seen that one equalizer circuit and one charging circuit with its automatic cut out, are common to all the dynamos that may be used. While this arrangement possesses all the flexibility of the method of installing a single series of cells as shown in Fig. 3, it has the additional advantage that at such times as the load is below normal, a spare dynamo can be exclusively employed for charging the cells, and thus avoid loss of energy in the pressure equalizer. As a general thing when the current equalizers, *c. e.*, have once been adjusted at the beginning of a charge they need but little if any further attention, still if from any cause one series of cells should happen to be overdischarged, or discharged more than the remaining series a suitable readjustment of the current equalizers will permit the undercharged series to receive current at a higher rate than the others, and thus equalize itself with the others. It may also be mentioned that both the pressure and current equalizers may be made to operate automatically by the application of a potential magnet to the former, and of a current magnet to the latter, together with a simple but somewhat expensive train of gears to move their levers. This is found to be wholly unnecessary in practice, however, as an engineer is usually in constant charge of such a plant while the dynamos are running, and he can easily devote the little time necessary to the infrequent regulation required.

It was mentioned in the early part of this paper that it was possible to injure accumulators either by overdischarging them or working them at too high a rate. It is assumed that, in the larger plants, there will be such supervision available under ordinary working conditions that occurrences of this kind will be avoided; but a simple device for preventing such abuse of the cells in smaller plants, where such supervision is not always convenient, has been devised. It is called an overload and over dis-

charge switch, and its operation is based on the fact that, when a series of cells is overdischarged, their potential falls below a minimum value, and that when they are worked above their normal rate the current exceeds a maximum value. The appa-

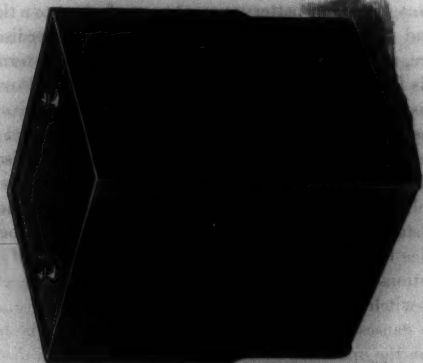
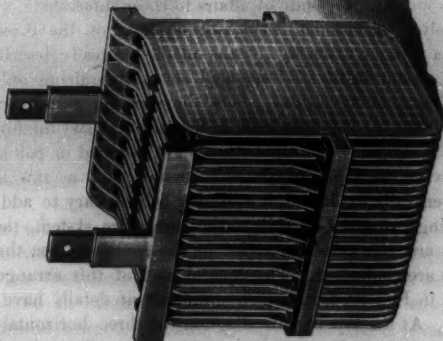


FIG. 18



ratus consists essentially of a pressure-magnet connected to the terminals of the battery, and of a current magnet in series with the battery; when the potential of the battery falls below a minimum value, the armature of the potential magnet is released and throws an artificial resistance into the battery circuit, and

thus reduces the current; and similarly, when the current exceeds a maximum value, the armature of the current magnet is attracted and performs a similar function. The connections of this overload and overdischarge switch, *c* and *p*, are shown diagrammatically in Fig. 7, in which a common resistance, *R*, serves for either magnet. The battery current passes from *a* to *b* through the overload magnet, while the terminals of the overdischarge magnet are, as before stated, in shunt to the battery terminals. In Fig. 8 is illustrated a practical form of a combined overload and overdischarge switch.

With the object of reducing the cost of the regulating apparatus whenever both the combined overload and overdischarge switch and the current equalizer are to be used with the same series of cells, the switch portion of the equalizer may be mounted on the resistance frame; and thus a single resistance coil be made to do service for both instruments. This combination, of which the connections are shown in Fig. 9, while allowing the current equalizer switch to control the full range of resistance, at the same time causes the whole coil to be thrown into the battery circuit upon the operation of either the overload or over discharge switch. This, of course, diminishes the brilliancy of the lamps, and thus indicates the state of affairs to those interested.

In applying accumulators to plants operated on the three-wire system, a simple extension of the method already described is adopted, except in the case of small stations requiring only one series of accumulators, and where the working circuits can be multiplied during the light load, so that the ordinary method will suffice. In larger plants the batteries are installed in pairs, each series having the same apparatus as before; and as this has already been fully explained, it will only be necessary to add that, in adapting two series of cells to the three-wire system, the two batteries are connected in series in the same manner that the dynamos are connected. The general plan of this arrangement is shown in Fig. 10, from which unimportant details have been omitted. At the top of this diagram the three horizontal lines *m* (+), *m* ($\pm$), and *m* (—) represent the omnibus wires in the dynamo room, from which the feeders, *i*, are led. The three vertical lines, *o* (+), *o* ($\pm$), and *o* (—), are extensions to the omnibus wires to which the dynamos are directly connected in the usual manner when the levers of the switches, *s*, are on their upper contacts. The batteries are also connected with the omni-

bus wires in a similar way, so that when the switches, s_2 , are closed on their lower contacts the batteries will also discharge into the lamp circuits in parallel with the dynamos. Now, if the switches, s_1 , are turned to their lower contacts, and the switches, s_2 , to their upper contacts, the current from the dynamos will divide at the switches, s_1 , part going into the lamp circuits, and part through the batteries, which thus receive a charge. As in the multiple-arc system, the potential of the dynamos being assumed to be raised above the normal to meet the requirements of the batteries, in order to suitably reduce the pressure on the lamp circuits, it is only necessary to adjust the resistance of the pressure

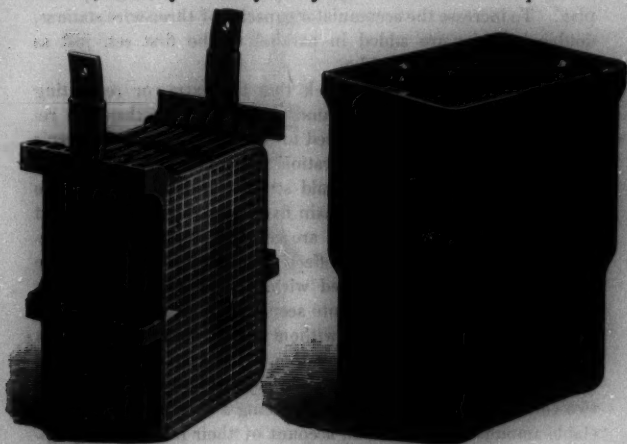


Fig. 19.

equalizer, *r* *e.* In central stations where the feeders are already provided with pressure equalizers the connections are still more simple, for the batteries are merely connected to the omnibus wires, while all other connections of the ordinary three wire station are unchanged. In such cases, the increased pressure at which the dynamos are operated during the time the batteries are charging, is reduced at the lamps to the proper point by the usual adjustment of the feeder or pressure equalizers. During the charging period all regulation of the accumulators may be dispensed with by opening the switch s_1 , when both batteries will be connected in a single series to the full pressure of both dynamos.

In addition to the apparatus shown in the diagram, each series of cells is provided with a double plug switch and sockets suitably disposed, by means of which the relative positions of the batteries on the two sides of the system may be changed by simply transposing the plugs from one socket to the other. The object of this arrangement is to provide means for compensating for the unequal discharge of the batteries when the two sides of the lamp system are unbalanced; and the transposition is never made oftener than once each day. In all other respects the manipulation of accumulators when applied to three-wire systems is practically the same as when they are operated on the multiple-arc plan. To increase the accumulator capacity of three-wire stations, double batteries are added in parallel to the first set, just as additional dynamos would be.

It was explained further back that the extra, or regulating cells, in each series often became charged sooner than the remainder of the cells, and required to be removed from the circuit before the others. This operation, of course, calls for some labor; and, little as it is, it would still be desirable to have the number of cells in a series remain fixed both during charge and discharge. By the use of what are called counter-electromotive-force cells, this result may be effected, and at the same time the pressure equalizer be dispensed with. These very simple cells are made like an ordinary Plante accumulator of plain sheets of an inoxidizable lead alloy and without active material. When a current is passed through them they act as gas voltmeters, and while they instantly oppose a counter-electromotive-force of about two volts, they are incapable of producing a current of any appreciable amount or duration on account of their inoxidizable property. The use of counter-electromotive-force cells in place of equalizers is advantageous in several ways, for not only may their internal resistance be made so small as to be practically negligible, but their counter-electromotive-force is as effectual in reducing excessive pressure as a dead wire resistance, while possessing the unequalled advantage that the fall in potential of the current passing through them is unaffected by any variation in the strength of such current.

The method of using these counter-electromotive-force cells is shown in Fig. 11, which represents a single series of accumulators installed in connection with a direct lighting plant operating one dynamo, as first described, and for simplicity and effectiveness

this method cannot be well exceeded. The dynamo is connected to the lamp mains, as before, through an ammeter on one side, and through the upper contact of a two-way switch, *s*, on the other; while the battery, *b*, is similarly connected to the lamp mains on one side, but on the other the circuit is completed through several counter-electromotive-force cells, *k*, the number opposed being governed by the position of the cell regulating switch, *c s*. When the lever of switch *s* is on its lower contact, the charging circuit is completed in the now familiar manner. The action of a plant arranged in the above way is as follows:— Assuming the lever of the cell-regulating switch to be turned off,

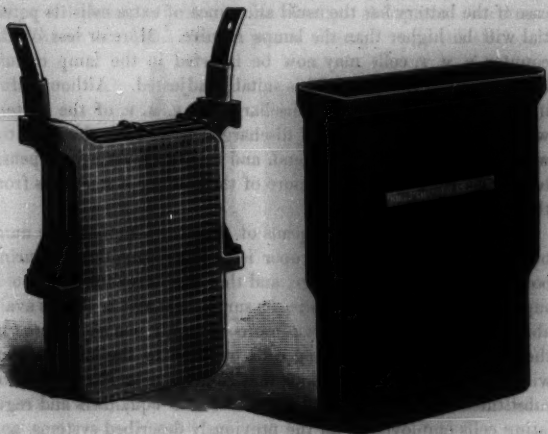


Fig. 20.

or open, as the expression goes, and that the dynamo switch is on its upper contact, the dynamo alone supplies current to the lamp circuits. If, now, the lever of the cell-regulating switch is turned to its left hand contact plate, the battery will be similarly supplying current to the lamp circuits in conjunction with the dynamo, or alone if the dynamo switch is opened. If the dynamo switch is now turned to its lower contact, the dynamo current will divide at the point where it connects between the battery and counter-electromotive-force cells, part going through the battery and back to the dynamo through the (—) lamp main, while the remainder will pass through the counter-electromotive-force cells to the

lamps. Thus, while the full pressure of the dynamo current will be effective at the battery terminals, its pressure at the lamps will be less by 2, 4, 6, etc., volts, according as 1, 2, 3, etc., counter-electromotive-force cells are opposed to the passage of the current into the lamps by the position of the lever of the cell-regulating switch.

When the battery has been fully charged and it is desired to stop the dynamo, the latter may be disconnected by opening the switch *s*, when the battery alone will maintain the lamps. As previously explained, the potential of the battery will be a maximum immediately after it has received a charge, so that in this case if the battery has the usual allowance of extra cells its potential will be higher than the lamps require. More or less of the counter *E. M. F.* cells may now be inserted in the lamp circuit, however, until the potential is suitably adjusted. Although during the greater part of the discharge the *E. M. F.* of the battery will remain fairly constant, if discharged to its limit the potential will slowly fall towards the end, and this fall must be compensated for by removing one or more of the counter *E. M. F.* cells from the lamp circuit.

It is to be noted that by means of the above method, the number of cells in the battery proper is fixed and unalterable during both the charge and discharge, and that whenever the dynamo is supplying current to the lamps, its surplus current is always available for charging the battery; moreover, only one adjustment of the counter *E. M. F.* regulating cells opposed to the lamp current will be required. It is obvious that counter *E. M. F.* cells may be substituted with equal effectiveness for the equalizers and regulating cells employed in all the previously described systems, and it seems unnecessary to go into any further particulars in order to illustrate the practicability of such systems when properly installed and operated.

We have now to consider another branch of the electric lighting business, in which accumulators also claim a share of attention, viz.:—the supplying of current to lamps located at a considerable distance from the source of power.

The first method to be considered, is known as the half direct plan, in which one or more series of cells are installed in any number of sub-stations conveniently located near centres of lamp consumption. The charging station may be situated wherever economy dictates, without any special reference to the location of

the batteries, for although the expense of the charging wire and the cost of the energy wasted in it, cannot be neglected, both these factors must be offset by the saving effected from locating the power station in the most desirable situation. This half direct system is so called because during the period of maximum load half the current is supplied by the charging dynamo, and half by the batteries. At other times the dynamo may be simultaneously charging the batteries and supplying lamps, or the battery alone may be in operation. Each sub-battery station is, in fact, a small central station by itself, and it may contain one or several series of cells, the number of course, depending upon the amount of lighting to be done in its vicinity. A common charging main, like an arc light circuit, passes through each sub-station.

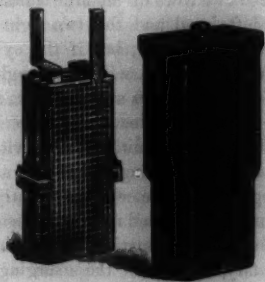


Fig. 21.

and each battery may be inserted in the main or withdrawn from it at will, exactly as arc lamps are cut in and out of circuit. The charging dynamo is usually of high voltage and of moderate current capacity; machines of 500 volts and 15 amperes to 1,200 volts and 40 amperes may be employed in small stations, while in larger ones the latter machines and their circuits may be multiplied. For charging purposes shunt wound dynamos are preferable on account of their non-reversibility, but even series and compound wound machines may be used if suitable precautions are taken. The arrangement of the accumulators and regulating apparatus in each sub-station on the half direct system is essentially the same as the method adopted in the last described multiple-arc system. The connections of two sub-stations installed on this plan are shown in Fig. 12, in which station 1 is shown with its switches in position for both its battery and lamp circuits to re-

ceive current from the charging circuit; while station 2 is disconnected from the charging line, which is closed outside of it, and the batteries alone supply the lamp circuits. The switch which is employed to throw the batteries into and out of the charging circuit is of the snap action type, and is sometimes called a consumer's switch. It maintains the integrity of the charging circuit when the batteries are removed from it, and is provided with a spark coil which prevents the opening of the charging line and the consequent formation of the injurious arc which results on the interruption of high potential circuits. A modified practical form of this switch is illustrated in Fig. 13. As shown diagrammatically in the sketch, it consists in the main of four terminal contact springs which bear against an insulated cylinder in which are embedded two rows of metallic contact strips. In one position the two left hand and the two right hand springs are brought into electrical contact, but if the cylinder is rotated slightly the two middle springs will be brought into electrical contact, while the two outer ones are left free, as shown respectively at R and R₁. As before stated, this change is effected rapidly and without breaking the circuit. These switches are usually operated by hand at the beginning and end of a charge, at which time whatever inspection of the cells is necessary is also generally made. By applying the polarized magnet principle to this switch it can be made to operate automatically from the central station through a momentary reversal of the charging current, a principle which has already been applied.

While the method just described of locating the batteries in sub-stations near the lamps to be supplied, reduces the resistance of the supply wires to such an extent that the variation of potential with changes in current strength is unimportant compared with what it would be were all the lamps operated from one central point, under ordinary conditions, still a similar variation does occur from a different cause. We have already seen that the potential of a battery is higher while it is being charged than at other times, and that the greater the charging current the higher the potential of the battery becomes. It is evident that if charging commences when only a very few lamps are burning on a given battery only a small part of the charging current will be required by the lamps, while the greater part will pass through the battery. This will raise the potential of the battery considerably, and as the lamp mains are permanently connected to its

terminals, the lamps will receive an excessive pressure. As the number of lamps increases, however, more of the charging current will pass to them and less through the battery, the potential of which thus becomes gradually reduced until it reaches a minimum, when the number of lamps burning becomes so great that the whole output from both the dynamo and battery is required to maintain them. The variation is in the opposite direction, of course, when the lights are diminishing in number. It is evident from the preceding facts that during the period when the charging dynamo is running and the lamp loads are varying, some regulation of the pressure at the lamp mains at each sub-station is required. This regulation is automatically effected by means of the apparatus shown in Fig. 14, in which a solenoid magnet, *A R*, and a polarized magnet *P M*, are inserted in the battery circuit. In all other respects the relative positions of the battery, lamps and charging circuits remain unaltered from the arrangement shown in the last diagram. The operation of the apparatus in this sub-station will be as follows:—Assuming the charging dynamo to be delivering a current through the charging main, *M*, and that the consumer's switch is in the position shown in the diagram, the charging current will pass from *M* (+) to the point *Q*, where it will divide, part going through the lamps and the opposed counter-electromotive-force cells, *K*, to the point *I*, and thence to the line again, the remaining part of the current passing from point *Q* through the magnets *P M* and *A R*, and out through the battery to point *L* and line. When the current is flowing in the direction of the arrow, as in the case just cited, the armature of the polarized magnet is moved to its left hand contact as shown, and the plunger of the solenoid magnet is more or less drawn down, according to the strength of the current. This action of the solenoid magnet causes one or more counter-electromotive-force cells to be inserted in the lamp circuit in such a way as to oppose their electromotive force to that of the charging current, while the full pressure of this current is available at the battery terminals. If now the number of lamps is increased to such an extent that not only all of the charging current passes through them, but also that more or less current from the battery joins in parallel with it; then the current from the battery will traverse the polarized magnet in the opposite direction from that previously taken by the charging current, and its armature will be moved against its right hand contact, thus short circuiting the

solenoid magnet and the counter-electromotive-force cells, as indicated by the broken line. For, as the sketch shows, the lever of the solenoid magnet is so balanced that when no current is traversing the magnet, its metallic contact rods all dip into their respective mercury cups, and so shunt around the counter-electromotive-force cells with which the latter are in electrical connection. When the lamp load becomes reduced and the charging current is discontinued either by the stoppage of the dynamo, or by its being shunted past that particular battery by a movement of the switch *s* to the right, the battery alone works into the lamp circuit, and the counter-electromotive-force cells are short circuited.

While the automatic regulator just described, when applied to the half direct system, maintains the pressure at the lamps sufficiently uniform for practical purposes, whether the charging dynamo is operating or not, and although the proximity of the battery to the lamps it supplies, prevents undue variation of potential when the load changes; yet a perfectly automatic method of maintaining a constant potential at the lamp circuits, even where the resistance of the leads is great, would be generally useful. Such a method is illustrated in Fig. 15, in which the battery, counter-electromotive-force cells, lamps and charging circuits occupy the same relative positions as before. The solenoid magnet of the regulator is no longer in series with the battery, however, and is, in fact, entirely disconnected from it, while the polarized magnet is replaced by a second solenoid magnet, *r m*, wound to high resistance. The armature lever of this second solenoid is so mounted that when its core is attracted or released this lever moves over a series of contact strips which are insulated from each other. Connected with these contact strips are coils of wire of suitable resistance, the whole constituting a simple rheostat, more or less of the wire of which is included in a local circuit, according to the position of the lever which acts as a movable contact. The solenoid magnet of the regulator *A R* and one or two cells of accumulators are also included in the local circuit referred to, the strength of the current flowing in this circuit depending upon the amount of resistance inserted by the movement of the lever of the pressure magnet *r m*. The latter magnet is connected directly with the battery terminals, and as the potential of the battery rises and falls the current flowing through this magnet varies correspondingly, causing a similar

variation in the current in the local circuit. Thus an increase of pressure at the lamps, which are connected to the battery terminals, indirectly causes the armature of the regulating magnet A to be attracted, and this in turn opposes one or more counter-electromotive-force cells in the lamp circuit until the pressure again becomes normal. If the pressure at the lamps falls below normal the regulator acts in the reverse way, cutting out the counter-electromotive-force cells until the normal pressure is again restored. If in connection with this method the polarized consumer's switch, previously mentioned, be substituted at s , the operation of such a sub-station will be entirely automatic.

It is proper to mention that the pressure magnet must be very sensitive and requires a delicate adjustment, besides being somewhat costly on account of the excellence of the workmanship required. Although I have only seen the instrument used in an experimental way, its practical application to similar purposes has given satisfactory results.

Under certain circumstances, as, for example, when a lighting station is worked to its full capacity at night but during the day time has ample surplus power, the all-accumulator system may often be applied to increase the capacity of such a station with satisfactory results. In such cases the sub-stations of accumulators are located at distant points in the usual way, the cells being charged during the day and discharged on the lamp circuits at night while the power plant is doing its regular work. The arrangement of the accumulators and regulating apparatus in the sub-stations of the all-accumulator systems is practically the same as when the half direct system is employed, except that a simple transfer switch which transfers the battery from the lamp circuit to the charging circuit, and *vice versa*, is used instead of the consumer's switch.

It is needless to say that all of the methods which have been described of employing accumulators in long-distance lighting may be adapted to existing lighting plants, and that when so adapted the earning capacity of such stations may be considerably increased without extending the capacity of the power plant. For this purpose there will usually be required a special dynamo at the central station, a charging circuit taking in the territory outside of the regular lighting limits, and one or more sub-stations with accumulators.

There are, of course, numerous other ways of utilizing accu-

mulators in central station supply systems, such, for example, as the double battery method now operated in England by the Electrical Power Storage Co., in which the dynamos are kept running for 24 hours daily, duplicate sets of accumulators being alternately inserted in the charging and supply circuits at uniform intervals of time, by an automatic mechanical device. But I have limited this paper to a description of some of the simpler methods of accumulator regulation which may be readily adapted to ordinary lighting plants, and, in concluding, can only hope that I have succeeded to some extent, at least, in showing that when so applied in an intelligent manner accumulators do occupy a useful place in the industry of electric lighting.

Through the courtesy of the Electrical Accumulator Co., I am enabled to present to the Institute this evening the first proofs of some cuts of a new line of standard accumulators recently brought out by that company. The cells referred to are shown in Figs. 16 to 21 inclusive, and their dimensions and capacities are described in the following table:—

LIST OF ELECTRICAL ACCUMULATOR CO'S STANDARD CELLS.

(Approximate Data.)

Figure.	Type of cells.	Charging current.		Working rate and capacity. Amperes.				External Dimensions of jar. Inches.						Weight of complete cell.				Height over all connections.
		Normal.	Amperes.	Normal.		Maximum.		Glass.			Rubber.			Glass.	Rubber.	Lbs.		
				Rate.	Amperes.	Rate.	Amperes.	Length.	Width.	Height.	Length.	Width.	Height.					
16	15 L.	15 to 30	30	300	40	250	104	124	134	—	—	—	50	—	130	—	154	
17 & 18	23 M.	10 to 25	25	150	30	110	104	84	94	64	74	94	114	16	11	50	40	114
19	15 M.	5 to 15	15	100	20	70	74	84	94	44	54	64	74	11	7	35	25	114
20	7 M.	2 to 6	6	40	8	25	44	84	94	24	34	44	54	6	8	20	13	114
21	5 S.	1 to 2	2	8	3	6	—	—	—	14	18	64	—	4	—	—	24	7

Electromotive force of each cell is about 2 volta.

DISCUSSION.

MR. PRESCOTT:—(continuing orally). There is another method of automatically maintaining a constant potential at the lamp

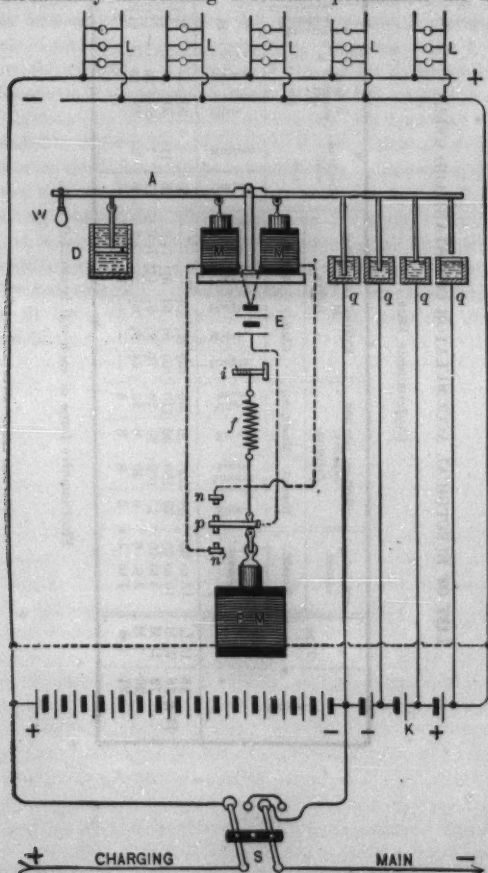


FIG. 22.

mains, which for special reasons, I had not intended to allude to. It is so interesting, however, that I will make a sketch of it on

the blackboard. In this diagram (Fig. 22) the lamp circuits l , are shown at the top, leading from the mains (+) and (-). Connected across the lamp mains, preferably at a point of average potential, is the solenoid magnet $r\ m$, which is wound with fine wire. The position of the plunger or armature of this magnet is so adjusted by means of the retractile spring f , that when the pressure is normal, the contact lever p , carried by the plunger, is midway between the local contact points n, n' . Probably most of my hearers are familiar with the Kohlrausch voltmeter, which is constructed on this principle of the solenoid magnet, and are aware that while it is not an entirely reliable instrument on account of variable friction and hysteresis, it still has a wide range and is very sensitive when the plunger occupies a given position. Now this magnet $r\ m$ depends on this fact, and only needs to be accurate for one position of its core. If, for example, the magnet is wound for 100 volts, then when it is connected with two points in the lamp circuit, having a difference of potential of 100 volts, the core will occupy a certain position. If the pressure exceeds 100 volts the core will be drawn into the magnet. If the pressure falls below 100 volts the core will be withdrawn by the retractile spring. This core of the pressure magnet is suspended from the adjustable shaft i on the spring f , and carries the local contact arm p , on its upper end. When the core is drawn into the magnet this is brought into contact with the screw n' , and when it is drawn out by the spring, contact is made with the screw n . So long as the pressure remains normal, the contact arm remains midway between the screws n, n' , for which position the primary adjustment must be made. If now the pressure becomes either excessive or below normal the circuit of the local battery π will be closed respectively through one or the other of the local solenoid magnets m, m' . The cores of these local magnets are attached to a balanced lever λ at equal distances from and on opposite sides of its point of suspension, and the whole constitutes a simple modification of the regulator shown in Figs. 14 and 15 of the paper. The necessary weight of the lever on the side carrying the contact rods which dip into the mercury cups q, q , etc., is compensated for by extending the lever for an equal distance on the opposite side of its fulcrum, and by adding a suitable counter weight w .

The operation of this apparatus requires that the lever should remain quiescent in whatever position it may be drawn by the action of either magnet m or magnet m' ; and that, moreover any

movement of the lever at all, tending to make or break contact with the mercury cups, should be very gradual. Both of these results are accomplished by introducing a slight friction at the point of suspension of the lever and by adding a carefully adjusted dash-pot *D*, in the manner shown in the sketch. Thus while the slight friction alluded to causes the lever to remain at whatever angle it may be placed, the dash-pot prevents the lever from moving except very slowly to whatever position the action of either magnet may tend to set it.

The function for which this regulator is employed is precisely the same as that performed by the somewhat similar regulator shown in Fig. 14 and 15, viz.: to insert in and withdraw from the main lamp circuit more or less counter-electromotive-force cells *K*, according as the pressure at the lamp terminals exceeds or falls short of the normal. The regulator acts in the following manner: Assuming the potential to be normal, the local contact lever *p* will stand midway between the contact points *n*, *n'*, and the regulator lever *A* will be horizontal as shown in the diagram. Now if the potential at the lamps increases, the core of the pressure magnet *r m* will be drawn down until it closes the local circuit through *n'* and magnet *m* and this latter magnet will slowly tilt the lever *p* towards its side, and thus cause first one and then another of the counter-electromotive-force cells to be inserted in the lamp main, thereby reducing its potential. When a sufficient number of cells have been inserted in the lamp circuit in this manner, to reduce the pressure again to normal, the core of the pressure magnet again resumes its normal position, breaking the local contact at *n'*, while the lever *p* continues to remain in its new position. If, from any cause, the pressure at the lamps now falls below normal, the attractive power of the solenoid *r m* will become correspondingly reduced, and the retractile spring *f*, will draw up the core until the contact lever *p* closes through the point *n*, the local battery circuit through the magnet *m'*. This causes the lever to be gradually tilted in the opposite direction from before, and therefore to cut out of circuit one or more counter-electromotive-force cells until the normal pressure at the lamps is again restored.

(It will be seen that this regulator thus automatically maintains a constant pressure at the lamp terminals, irrespective of the fact whether variations of this pressure are caused by the charging current, or by the resistance of the leads when the lamp load is altered.

MR. TOWNSEND WOLCOTT:—Mr. Prescott seems to place a great deal of reliance upon the voltage of the battery as an indication of the amount of charge left in it. If a battery is discharged in just a given manner, as far as my experience goes, the voltage will be determinate, but the higher the rate of discharge the sooner a low voltage is reached, and it is possible, just for experimental purposes, to discharge a battery at so low a rate as never to reach 1.8-10 volts, or even to go below say 1.9-10. In fact, I think by very slow discharge you could keep above 1.9-10 and still discharge so far as to spoil the battery. I suppose in practice the rate of discharge averages, in the class of work which is described, somewhere nearly constant, and the voltage may be a more valuable indication than it would be in traction work, or work of that character with which I am more familiar. I know in the Julien Company's work at Eighty-sixth street the voltage was no indication whatever of the charge left in the cells. There was a method which Mr. Julien introduced himself. The cells were divided into four groups, used sometimes in parallel and sometimes in series, and some of them would naturally be used more than others. So, in order to equalize them, the four groups were connected in parallel with each other, without any motor connection, the idea being that the cells at the higher potential would charge those at a lower potential; but as a matter of fact nothing of the kind occurs. After a few moments and a very slight discharge from the higher ones, they all come to the same potential, and where the cars were stuck on a grade, by waiting a few moments we would be able to go up the grade, or any tight place. This is another analogy to the animal that Mr. Prescott spoke of. By letting the battery rest, it gains sufficient energy to go up the grade.

MR. PRESCOTT:—The point Mr. Wolcott makes is perfectly correct, and unless the batteries are used under normal or somewhere near normal conditions, the potential alone is no indication of their charge. In the case where they are working at an unusually high rate, or discharging at a low rate, both the specific gravity and the potential would have to be taken into account. There the specific gravity would be the surest indication.

In regard to connecting several cells in parallel, I pointed out in the paper that where you are charging batteries in parallel and one set is more charged than another, the lower set does take more current for a while, but eventually its potential comes up

to the others. Therefore we are obliged to have the regulating device I spoke of, otherwise the potential and electromotive force must both be taken into account to determine the condition of the batteries.

THE CHAIRMAN (Vice-President T. C. Martin):—In case there are gentlemen here not members of the Institute desirous of asking questions, we should be glad to have them do so. We have with us here one or two gentlemen who have been abroad recently, and have seen some of those storage battery stations in London working on analogous principles to those described here. I think it would be interesting if we could be furnished with information as to what has been practically achieved at those stations. Reference has also been made to storage batteries as replacements for some of the apparatus in use. We have with us gentlemen who are connected with stations using such systems. I think it would be useful to know their opinion.

MR. JOHN W. HOWELL:—The first thing I would like to say, is, to congratulate Mr. Prescott on the work he has done. I am sure what he has shown us here has been the one thing, the absence of which has stood in the way of storage battery success in the past. I have had something to do with storage battery plants installed by the Electrical Accumulator Company and I knew that their lack of success at that time was due to the absence of what Mr. Prescott has shown here. At a previous meeting of the Institute, in the discussion of a paper, I said a storage battery was capable of being regulated beautifully, but that it was not done at that time. I am glad to see that it is going to be regulated, because it is a most valuable adjunct of the systems now in use and properly regulated, its value cannot be overestimated.

MR. PRESCOTT:—I might say incidentally that the use of these counter-electromotive-force cells would prove by themselves a great convenience and would be very economical in all central stations in which equalizers are now employed. Of course, there is a little loss of energy in them, but the great advantage is that variations in the load would not require variations in the adjustment of a number of counter-electromotive-force cells in circuit. So this form of regulator is applicable to any lighting system whether storage battery or direct.

MR. HOWELL:—The only objection to the substitution of a counter-electromotive-force cell for an equalizer, would, I think, be the fact that it is wet.

THE SECRETARY :—I would like to inquire of Mr. Prescott if the automatic device shown in Fig. 15 is considered a perfectly practical arrangement, or whether the delicacy he spoke of would not tend to operate against its general introduction. That is the case very often in devices of that kind.

MR. PRESCOTT :—In regard to that I would say that while I think it could be made to operate practically it would be expensive and rather complicated and this device that I have shown in Fig. 22 accomplishes the same purpose in a simpler, and I think, more efficient manner. The other, as a laboratory apparatus, I have seen work, but as a commercial appliance I doubt whether it will work with complete success.

MR. JOSEPH WETZLER :—Some reference having been made to work going on in London in the distribution of current by storage batteries, I would like to state that there are two stations there now, which have been under way for several months; one in fact has been running for a year or two. This station, which has been running the longer time—the Knightsbridge station—is under the control of Mr. Crompton. They have been running very successfully, so much so that they are now enlarging their plant very considerably. Where they formerly used but one wire, they are now running a three-wire system underground in a shallow conduit with bare conductors. The appliances in this station are very simple indeed, and are all regulated by hand, both at the main station and the sub-stations. The station which seemed to be more modern in the respect of automatic regulation is at Chelsea, where Mr. Frank King, well-known in connection with storage batteries, is engineer in charge. In that station the whole operation of charging and discharging, both at the main and the sub-stations, is done automatically, and I must say that the equipment of the stations is very elaborate indeed in the matter of switches and connections. Indeed it would require an elaborate explanation to show the various functions of the apparatus. Among others, it embodied, as a method of regulation, the discharge and accumulation of gas evolved from a cell in a bell jar which gave indication of the time for the complete discharge of the batteries by raising the jar and cutting it out from the charging circuit. That was only an incident, however. The station has been in operation for several months, and I was shown some of the sub-stations also, which were in charge of boys, one of whom told me that he was getting a pound a week. He was

the only attendant at the sub-station. His functions were merely nominal, as at the sub-station, also all the regulations were performed automatically. I must also add my quota to what Mr Howell has remarked regarding this paper, which I consider one of the best I have ever had the pleasure of listening to or reading.

THE CHAIRMAN :—My own opinion with regard to so valuable a paper is that it is somewhat of an injustice both to the paper and its author to discuss it off-hand. Such a paper as this could hardly be dealt with in a hurry, and therefore I think it would be well, if in view of the lateness of the hour, any gentleman who wishes further to discuss it, were to commit his views on the subject to paper, and we should be very glad to give him precedence and a hearing at the next meeting. Unless there is anything pressing on the mind of any gentleman at this moment of which he must deliver himself, I think that would be the better course.

Before a motion to adjourn is received I would like to state that at our next meeting, on November 19th, we shall have a paper from Mr. C. J. Reed, on a very interesting subject, "The Form and Efficiency of Incandescent Lamp Filaments." Mr. P. B. Delany will also bring before us some telegraphic improvements, including his own work in the devising of the Delany line-adjusting system, and one or two other matters. This paper of Mr. Delany's will be illustrated with practical demonstrations.

THE SECRETARY :—I have a matter that I think we ought to bring before the meeting before adjournment. You will all remember that the various engineering societies were represented in England during the past season and visited the Paris Exposition. The tour was begun too early to permit of the organization of a party from the electrical engineers, the other engineering societies leaving about the first of June. But several of our members were in that body, and as the Institute had been officially invited, President Elihu Thomson of the Institute was there as our representative. At a banquet given by the Lord Mayor of London, at the Guild Hall, on the 13th of June, where the various engineering societies were represented, President Thomson responded to the toast of the American Electrical Engineers, and the Secretary of the Institution of Civil Engineers has been so kind as to forward a transcript of Professor Thomson's remarks on that occasion, and I would be glad to

read them to you, for I am sure you will all be pleased to hear what he said :—

PROFESSOR ELIHU THOMSON:—My lords and gentlemen: It is my privilege, as the chief officer of a young, vigorous and growing organization, the American Institute of Electrical Engineers, to express its thanks for the opportunities and hospitalities which have been so freely and graciously extended to it by our English brethren. The electrical engineering profession is in fact a very recent extension, a division of engineering. I need not remind the eminent gentlemen here assembled, many of whom have been far better witnesses than myself of the fact, that scarcely more than ten years ago the electrical engineer had no part or place in the activities of engineering. It is true that the telegraphic expert was in a somewhat restricted sense an electrical engineer. It is more true that we have with us one whose scientific and mathematical genius made the difficult problem of ocean telegraphing an engineering success, and who, therefore I am quite sure you will agree may be called the father of electrical engineers. The name of Sir William Thomson, engineers in general will be prepared to honor as the great master who, in addition to his numerous labors, has given and continues to give the electrical engineer instruments which are as his rule and square and compasses. But in him also we find the type of the true scientist to whom all truth is of equal merit. I can say for the electrical engineers of America, as representing their Institute, that the present opportunity of uniting with the civil, mechanical and mining engineering professions in celebrating the present memorable occasion, and particularly in extending thanks for the most hospitable and gracious privileges so freely accorded to them in England, will be long remembered and cherished. We are glad of the harmonious relations thus so auspiciously established with those on this side of the Atlantic who are carrying on work similar to our own, the growth and extension of which relations cannot but have the most beneficial effects on the work itself, but must even become a factor in uniting our national interests for the general advancement of the human race. The work of the electrical engineer is in a field of constant expansion; much work has been done, far more remains to be done. It is difficult for those unacquainted with the nature of the problems presented in a field so new to realize to the full, the hard-fought battle with difficulties and against obstacles resulting in the victories thus far achieved. It has been required of the electrical engineer that he unite the qualities of the mechanician, the chemist, the physicist and general technologist, with those of patience and tenacity of purpose. He has been, as it were, a pioneer in a new country, with rocks and fallen trees lying in his path. The materials of construction alone, with whose properties he must be acquainted, cover a vast range of available substances and manufactures.

For confirmation of this, all that is required is to inspect the stock rooms of our largest electrical manufactories. Many materials before unknown to the trade have been demanded in the work. The field of operation is wide. Electric metallurgy, telegraphy, telephony, arc lighting, incandescent lighting, motive power transmission and electric railways, electric welding, soldering and metal working, electric tanning, besides a host of other operations in which electricity plays a chief part, now afford scope for the activities of the electric engineer. Who is to say where the growth and development will stop? Will we not light our houses by electricity, giving light without heat? Shall not the time come when we may burn our coal, produce electricity in efficient amount therefrom, and thus supplant steam engines for motive power, and dynamos for electrical work? Shall not the great water powers be turned to account to propel our railway trains, to do our metal work, to light our streets and buildings, to run our factories, and to effect our chemical operations such as bleaching, tanning and others? Shall not we even store up power in substances possessing high chemical affinities, which power may be let out or recovered at any time hereafter for the uses to which electricity is now applied? Shall we even dare to hope that electrical communication on the Atlantic may be maintained with our friends and dear ones ashore? I believe that these things and more lie in the path which the electrical engineer of to-day has but begun to tread. As one of the oldest and greatest of philosophers has said of man, "For who shall bring him to see what shall be after him," we can certainly set no limit of achievement in this new field; we have at last laid hold of the properties of the universal ether to do our work, and its universal character will no doubt be exemplified in its applications to such work. As a delicate controller, as a transmitter of ideas written or spoken, as a giant mover of masses, as a lantern bearer, as a storer and carrier of power, as the most powerful and yet most delicate chemical reagent, as a heating agent under perfect control, and in many other ways, the ether has been called to do man's bidding, that wondrous agent which has place in nature, co-extensive with nature itself. In these allusions to electrical work I cannot forget, that to theoretical science in England, and to its great leaders, we owe much of the growth and development which have led to our beginning, feeble as it yet is, of an understanding of the nature of electric and magnetic phenomena. In conclusion, I join in the heartiest manner in the response to the toast in expressing for myself and the society which I represent a most thorough appreciation of the friendly spirit and kind wishes shown.

THE CHAIRMAN:—I am sure it is gratifying to us to know that our society received this honor, as no greater honor can be bestowed in London, at least, than a banquet at the Guild Hall.

There is one other honor of the kind, and that is the freedom of the city, and it may be interesting to you to know that that honor would have been bestowed upon another of our members had he remained long enough in the country to receive it. I refer to Mr. Edison. I think as members of the Institute we have great reason for pride and pleasure in knowing that our President made so perfect a response in our behalf.

Adjourned.

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